MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

Madurai – 625 021.

DIRECTORATE OF DISTANCE EDUCATION

M.Sc., Botany

Paper – I

PLANT DIVERSITY

(Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms)

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Syllabus
First year

Paper I: PLANT DIVERSITY (Algae, Fungi, Bryophytes, Pteridophytes and gymnosperms)

Phycology: General account (habiat, thallus organization, cell structure and reproduction). Criteria for classification: pigments, food reserves and flagella. Classification (Fritsch). Salient features of cynophyta, Cholrophyta, Bacillariophyta, phaeophyta and Rhodophyta. Ecological significance; Economic importance

Mycology: General characters; sustrate relationship, structure, cell wall composition, nutrition, and reproduction, hetrothalism, parasexality; recent trends in classification. General account: mastigomycotina, aycomycotina, ascomycotina, basidiomycotina, deuteromycotina. Outline of ecological significance and economical importance of fungi. Lichens- general account; economical importance.

Bryology: Morphology, structure and reproduction; distribution-Classification; Characteristic features of Hepaticopsida, Anthocerotopsida and Bryopsida. Ecological significance; Economical importance.

Pteridology: General account: Morphology, structure and reproduction; classification of pteridophytes; stellar evolution; Heterospory and orgin of seed habit. General account of fossil ptergophtes: Salient Features of psilopsida, Lycopsida, Sphenosia and pteropsida.

Gymnosperms: Introduction: general characteristics, distribution, classification (sporne) and Evolution of gymnosperms. Salient features of *Pteridopermales, Cycadeoidales* and *cordaitales*. Structure and reproduction in cycadales, ginkgoales, coniferales, ephedrales welwitschiales and Gnetales; Economical importance.

Text Book:

1. Alexopolus C.J. and Mims C.W. 1979. *Introductory mycology*. Wiley Eastern Limited, New Delhi.
2. Pandey B.P. 2001. *College Botany*. Volume I, S. chand & Company Ltd., New Delhi.
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5. Smith G.M. 1965. *Cryptogamic Botany*- Algae and Fungi (I). Tata MC Graw Hill Publishing Co. Ltd, New Delhi
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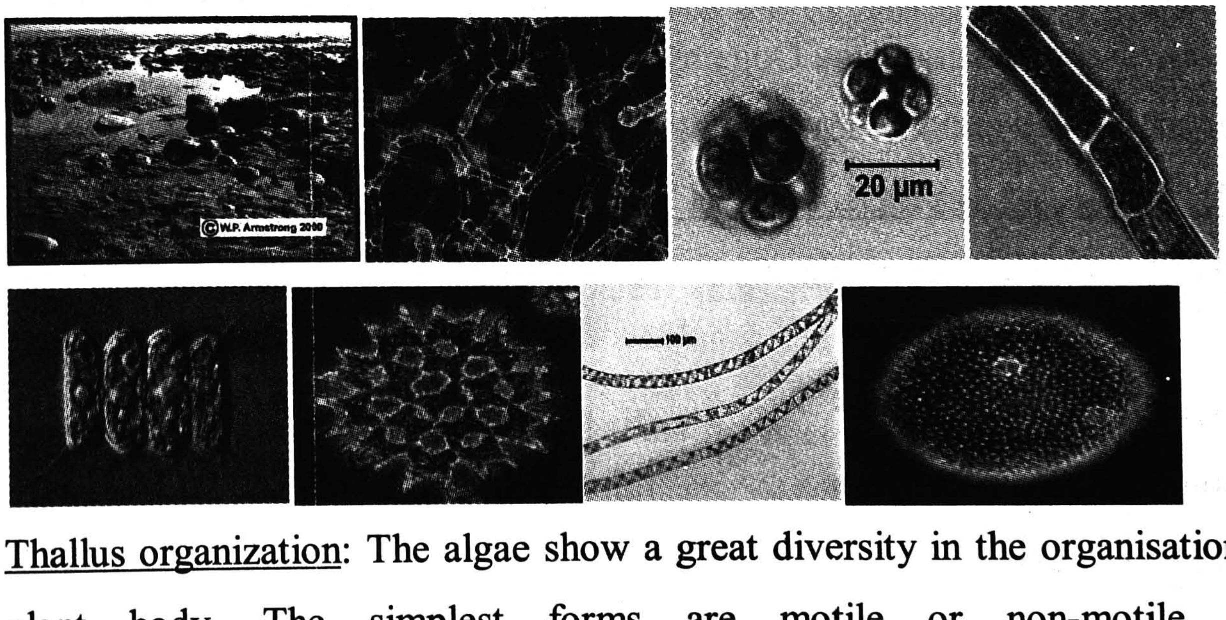
M.Sc., BOTANY (Non-Semester) First year

Paper I: PLANT DIVERSITY (Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms)

Phycology: General account (habitat, thallus organization, cell strucutre and reproduction). Criteria for classificaton: pigments, food reserves and flagella,. Classification (Fritsch). Salient features of Cyanophyta, Chlorophyta, Bacillariophyta, Phaeophyta and Rhodophyta. Ecological significance; Economic importance.

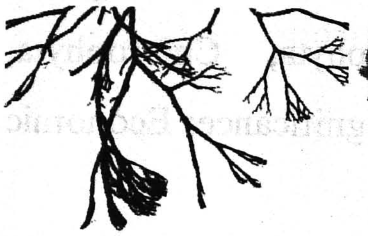
GENERAL ACCOUNT (Habitat, thallus organizaton, cell structure and reproduction)

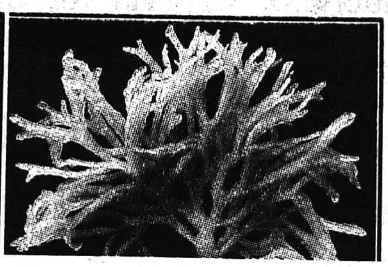
Habitat: The algae are found in fresh or salt water. Fresh water forms occur abundantly in ponds, lakes, slow flowing streams and water reservoirs. Some of the Terrestrial forms grow on wet trunks and branches of trees or on rocks. Some are endophytic growing in plants. Cyanophpycean algae like *Nostoc* and *Anabaena* fix nitrogen and found as a Symbiotic association with plants like *Anthoceros, Isoetes, Cycas* etc. Marine macroscopic algae are called Seaweeds. They may be free floating or attached on rocks or sands. Free floating microscopic algae are known as Phytoplanktons. The alge found at the bottom in shallow water are called Benthos.



Thallus organization: The algae show a great diversity in the organisation of the plant body. The simplest forms are motile or non-motile unicells (*Chlamydomonas* and *Chlorella*). In many species, the cells are grouped into

aggregations called colonies. Palmelloid and Dendroid types are non motile colonies with or without mucilage covering. Ex. *Tetraspora*. The filamentous alage may be free floating or attached Ex. *Oedogonium, Cladophora*. *Vaucheria* and *Calulerpa* consists of tube like filaments with branching. Advanced types shows monosiphonous or polysiphonous or parenchymatous filaments.





Cell Structure: Algal cells are two kinds, Procar yotic (Blue-green algae) and Eucaryotic (all other algae).The cell wall of Blue-green algae (Cyanobacteria) is very similar to Gram negative bacterial cell wall. DNA material is fibrillar. Mitochondria and Chloroplast are absent in the Cyanobacteria. Thylakoids with photosynthetic pigments are present. Eucaryotic cell has the same strucuture as of the higher plants. Cell wall is made up of cellulose. Nucleus, Mitochondria, Golgi body and endoplasmic reticulum and Chloroplast are present.

Reproduction: Algae reproduce by two methods viz. Asexual (includes vegetative propagation also) and Sexual. There are several methods of Asexual reproduction. They are... Cell Division, Fragmentation, Hormogones, Protonema, Akinets. There are three types of sexual reproduction viz. Isogamy (fusion gametes are in similar shape)Ex. *Ulothrix*, Anisogamy (fusion gametes are dissimilar in shape) Ex. *Chlamydomonas braunii* and Oogamy (Female gamete is large and nonmotile, male gamete is small and motile) Ex. *Chara*.

CRITERIA FOR ALGAL CLASSIFICATION

The primary classification of algae is based on five main criteria of a different nature:

1. photosynthetic pigments,
2. the nature of the food reserves
3. the types of flagella,

1.Photosynthetic pigments:

Colour is a quick guide to preliminary classification of an algae. However, the colour varies with changes in environmental conditions . An accurate classification depends on chemical analysis of the photosynthetic pigments.

There are three kinds of photosynthetic pigments in algae- Chlorophylls, Carotenoids and Biloproteins- The distribution of these is important in algal classification.

Chlorophylls:

Chlorophylls of different algae show different spectral properties. Based on that they are called, chlorophylls a,b,c,d and e.

Chlorophyll- a is present in all algae except photosynthetic bacteria.

Chlorophyll -b is found in higher plants, Chlorophyta, Euglenophyta and Charophyta.

Chlorophyll-c is present in members of Bacillariophyta, Chrysophyta, Pyrrophyta, Cryptophyta and Phaeophyta.

Chlorophyll-d is present only in the Rhodophyta

Chlorophyll –e has identified in only two genera of Xanthophyta, *Tribonema* and the zoospores of *Vaucheria.*

Carotenoids:

Carotenoids are of two kinds, Carotenes and Xanthophylls. Carotenes are linear unsaturated hydrocarbons and xanthophylls are oxygenated derivatives of these.

Carotene:

β -carotene is present in most algae.

α -carotene is present in the Caulerpales (Chlorophyta),Cryptophyta and Rhodophyta.

ε -carotene is present in Bacillariophyta and some members of Cryptophyta.

γ-carotene and Lycopene are found in Charophyta.

Xanthophylls:

Peridin is found only in the Pyrrophyta

Myxoxanthin is present in Cyanophyta.

Taraxanthin is in the Rhodophyta

Antheraxanthin is present in the Euglenophyta.

Biloproteins:

Chlorophylls and Carotenoids are soluble in organic solvents. Biloproteins are soluble in water or in buffers. Free pigments,phycocyanin and phycoerythrin can not be separated from a protein. Biloproteins are present only in three algal divisions, the Cyanophyta(C-type), Rhodophyta (R-type) and Cryptophyta(third kind)

The proportion of pigment varies. For example, Chlorophyta and Euglenophyta appear green because of an excess of chlorophylls over carotenoids,whereas Bacillariophyta and Phaeophyta are golden brown in colour because excess of carotenoids compared with chlorophylls. .

2. Food storage products:

'True starch' , similar to that found in higher plants, is only found in one algal division, the Chlorophyta. Rhodophyta and Cyanophyta, accumulate characteristic starches; these are floridean starch and myxophycean starch respectively. Others are Laminarin (Phaeophyta), paramylum (Euglenophyta) and chrysolaminarin, or leucosin (Chrysophyta and Bacillariophyta. Other storagae products of taxonomic importance include floridoside and mannoglycerate in the Rhodophyta, and the proteinaceous Cyanophycin found in cells of blue-green algae (Cyanophyta). Mannitol, a polyhydroxy alcohol found only in the Phaeophyta. Chlorophyta usually accumulate more carbohydrate than fat whereas cells of Chrysophyta and Bacillariophyta accumulate a high proportion of fat. Sterols are absent in Cyanophyta as in bacteria. . Sitosterol is the abundant sterol in higher plants, is also found in the Chlorophyta.. The green alga *Chlorella pyrenoidosa* accumulate ergosterol. Fucosteroll is a common sterol of the Paeophyta.

3. Flagella:

Flagella are absent in the Cyanophyta and Rhodophyta.

Nature, number and position of the flagella are important characters for the primary classification of the Algae. Flagella are two kinds: Acronematic (whiplash, smooth, peitschengeisel) and pantonematic (flimmer, flimmergeisel). 9

+ 2 pattern is present withinside the flagella.Minute scales and hairs are observed in the Prasinophyceae under electron microscope.

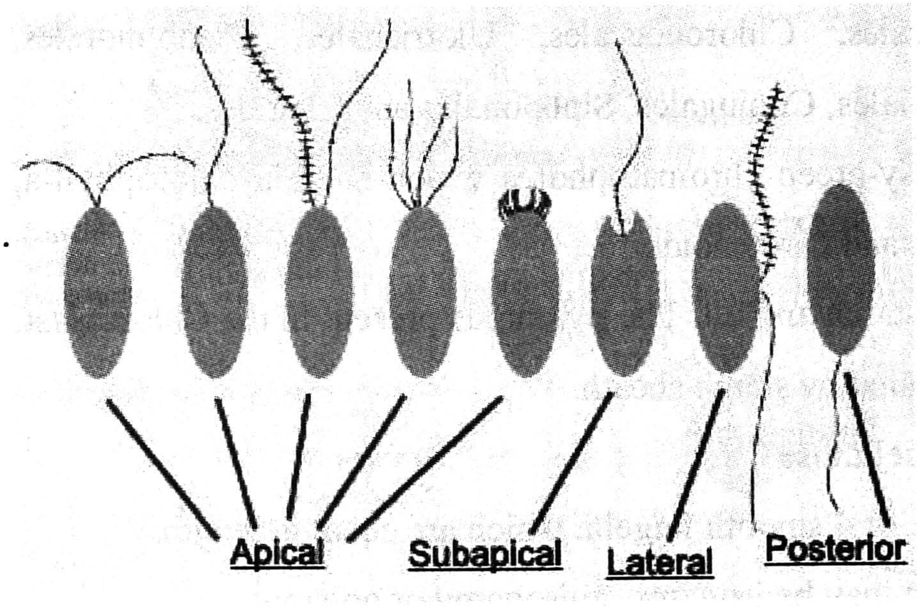


Figure-3

FRITSCH'S SYSTEM OF CLASSIFICATION OF ALGAE

Fritsch , ' Father of Algology', the well-known algologist of the Great Britain, has published two volumes of books entitled "Structure and Reproduction of the Algae" in 1935 & 45. He has considered algae as one group equivalent to a division and has divided living forms of this group into 11 classes. His system is the most comprehensive and authoritative account on algae even today. In classifying algae he referred Pascher and Tilden's classification. His classification is based on pigments, details of flagella, storage food, presence or absence of true nucleus in cells, range of thallus structures, methods of reproduction and patterns of life cycle, phylogeny, affinities and interrelationships of various forms of algae. He compared living algae with fossil forms . Fritsch divided algae into 11 classes. They are –

1. Chlorophyceae
2. Xanthophyceae
3. Chrysophyceae
4. Bacillariophyceae
5. Cryptophyceae
6. Dinophyceae.
7. Chloromonadineae
8. Eugleninae
9. Phaeophyceae
10. Rhodophyceae
11. Myxophyceae

1. Chlorophyceae

The members of Chlorophyceae are called green algae. This clsss includes 9 orders, namely Volvocales, Chlorococcales, Ulotrichales, Cladophorales, Chaetophoralels, Oedogoniales, Conjugales, Siphponales and Charales.

These algae have grassy-green chromatophores which contain chlorophyll-a, chlorophyll-b, xanthophyll and carotenoids.

Storage foods are true starch and oil. The pyrenoids present in the Chloroplast. The pyrenoids are surrounded by starch sheath.

The cell wall is rich in cellulose.

The motile cells have 2 or 4 smooth flagella which are equal in length.

The sexual reproduction may be isogamy, anisogamy or oogamy.

The thallus may be unicellular or multicellular. If multicellular, it may be filamentous or heterotrichous or siphonous or pseudo-parenchymatous.

Many species are haploid, but some are diploid.

They are more common in fresh water than in salt water.

Chlamydomonas, Volvox, Chlorella, Oedogonium, Caulerpa, Coleochaete etc are examples for green algae.

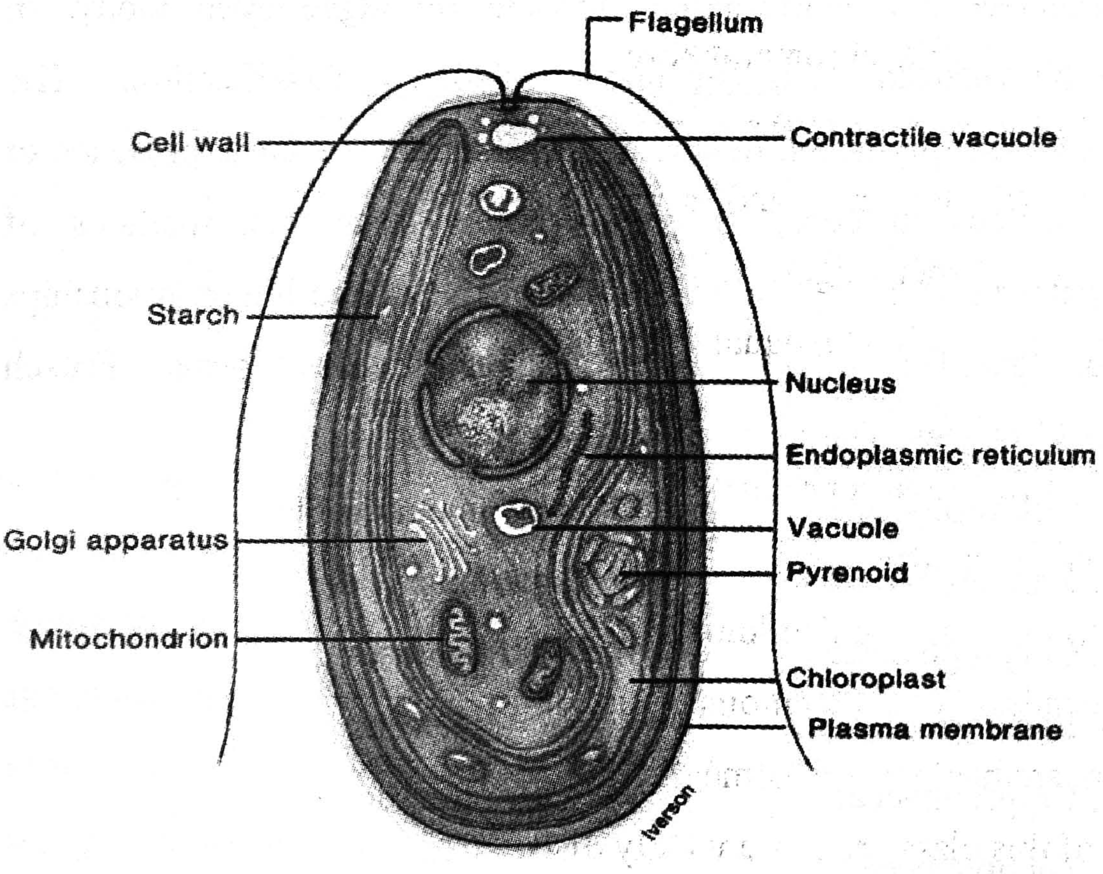


Figure-5

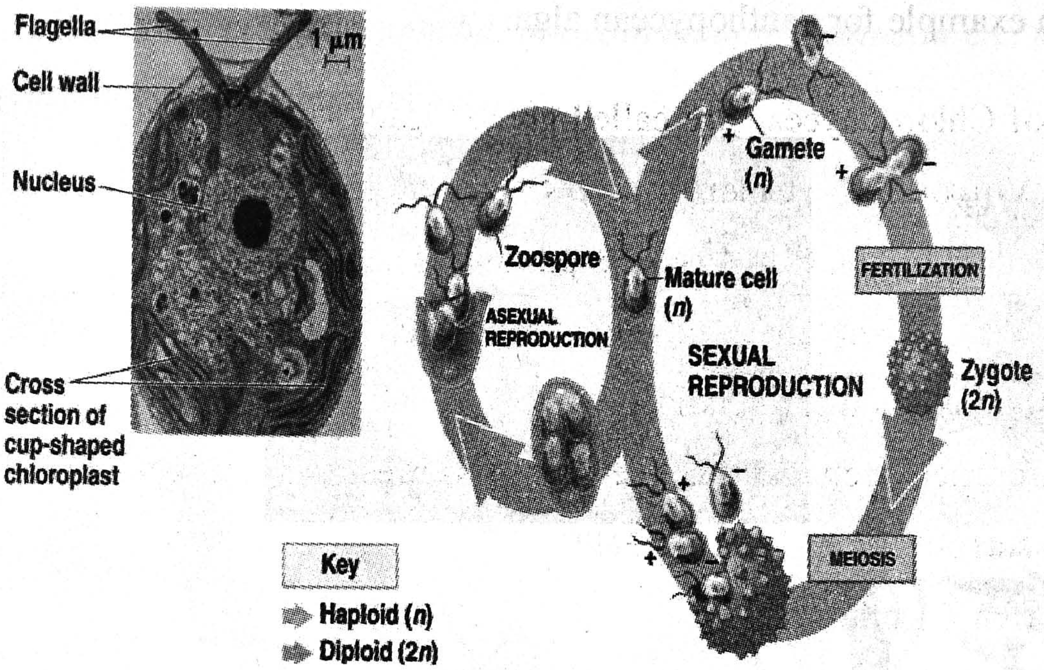


Figure-6

2. Xanthophyceae:

The members of this class are called yellow-green algae. This class includes 4 orders, namely Heterochloridales, Heterococcales, Heterotrichales and Heterosiphonales.

The chromatophores are yellowish green in colour due to excess of xanthophylls and small amount of chlorophyll-a, chlorophyll-e and carotenoids in them.

Pyrenoids are absent in the chromatophores.

Starch is absent. Reserve foods are stored in the form of oil and leucosin

The cell wall is rich in pectin, and is mostly made of two equal or unequal pieces of overlapaping at their edges. It is often silicified.

There are two (rarely one) unequal flagella at the front end of the cell, if motile.

Asexual and vegetative reproductions are common. Sexual reproduction is rare. It is isogamous, if present.

The thallus may be motile unicellular or multicellular. If multicellular, it may be palmelloid or dendroid or filamentous or siphonous.

Many members are haploid, but some are diploid.

The members of this class are more widely distributed in freshwater than in salt water

Vaucheria is an example for xanthopycean alga.

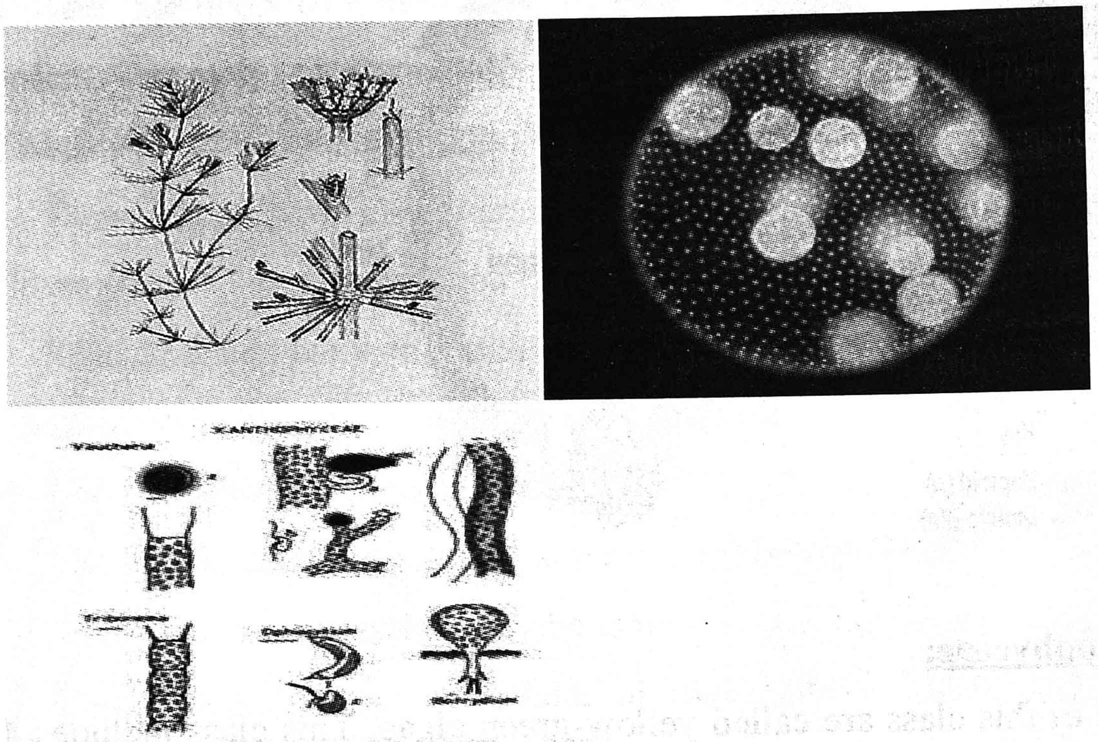


Figure-7

3. Chrysophyceae

The members of this class are often known as orange algae. This class includes 3 orders, namely Chrysomonadales, Chrysophaerals and Chraysotrichales.

The members of this class contain 1-2 brown or orange coloured chromatophores in each cell. These chromatophores possess excess of phycochrysin and small proportion of chlorophylls, β-carotenes and xanthophylls.

Pyrenoids are present, but are not enclosed by starch layers.

Photosynthetic reserves are stored in the form of fat droplets and leucosin.

The members of this class are mostly flagellates. The flagella may be one or two, rarely three. They may be equal or unequal.

Their cell wall is non-cellulosic, and bears silicified scales or calcified plates.

Sexual reproduction is rare. It is isogamous, if present.

The thallus may be a single cell or coccoid or palmelloid or dendroid or filamentous. The members of the class are mostly living in fresh water, but some are in marine water.

Mallomonas, Chrysamoeba, Phaeothamnion, Pedinella etc. are common representative of chrysophyceae. \

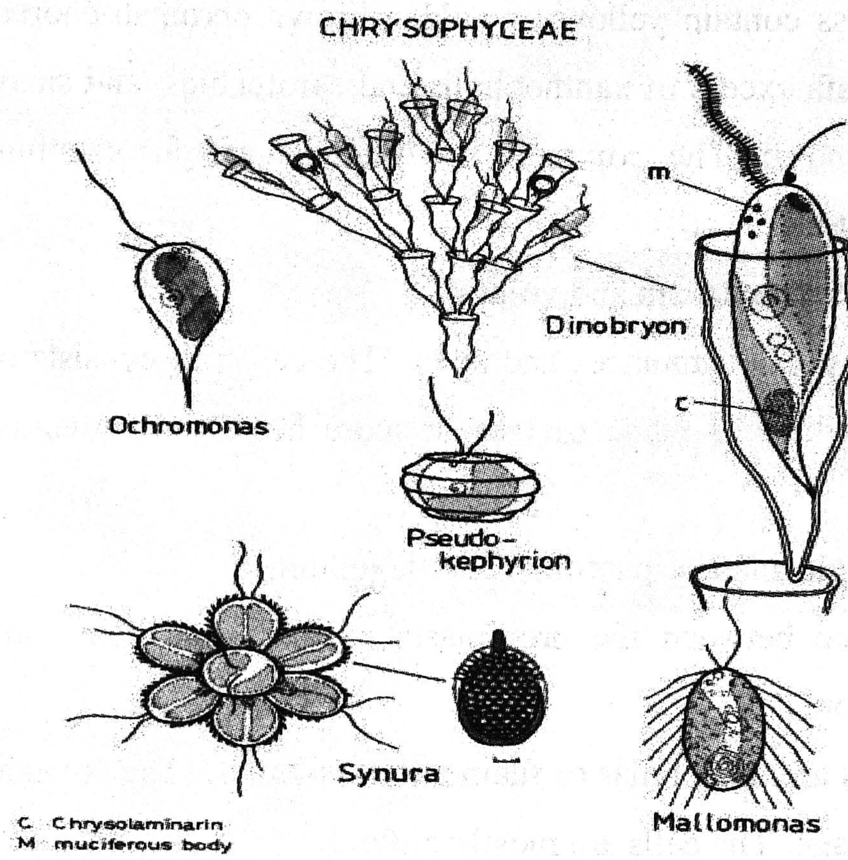


Figure-8

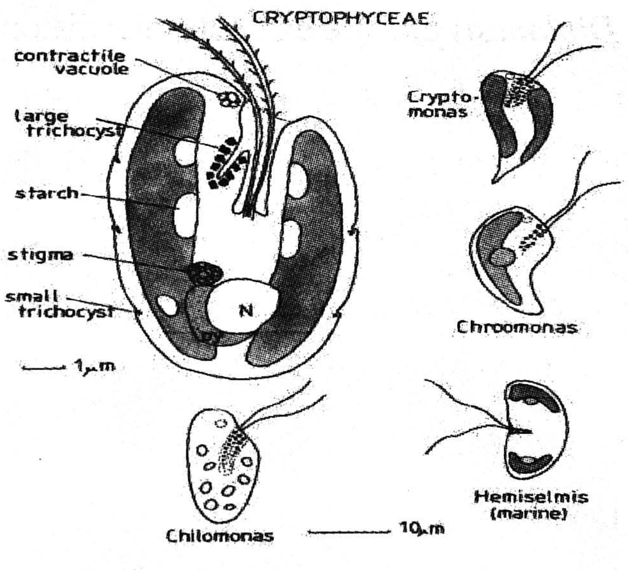


Figure-9

4. Bacillariophyceae

This class is called golden brown algae or diatoms. This class includes two orders , namely Centrales and Pennales.

The members of the class contain yellow or golden brown chromatophores. These chromatophores contain excess of xanthophylls and carotenoids. and small amount of chlorophyll-a and b. The common xanthophylls are fucoxanthin, diatoxanthin and diadinoxanthin.

The storage products are fats, leucosin and volutin.

The cell wall is made of pectic subtances and silica. The cell wall consists of two equal halves each of which is made of two or more heavily ornamented pieces.

Motile cells possess a single anterior pantonematic flagellum.

Sexual fusion takes place between the protoplasts of individual cells, and results in auxospore formation

The members of the class are unicellular or filamentous colonies. The colonial forms are enclosed by mucilage. The cells are mostly diploid.

They are widely distributed in fresh water, sea water soils and other terrestrial habitats

Pinnularia, Surairella, Triceratium, Diplonesis etc. are examples for diatoms.

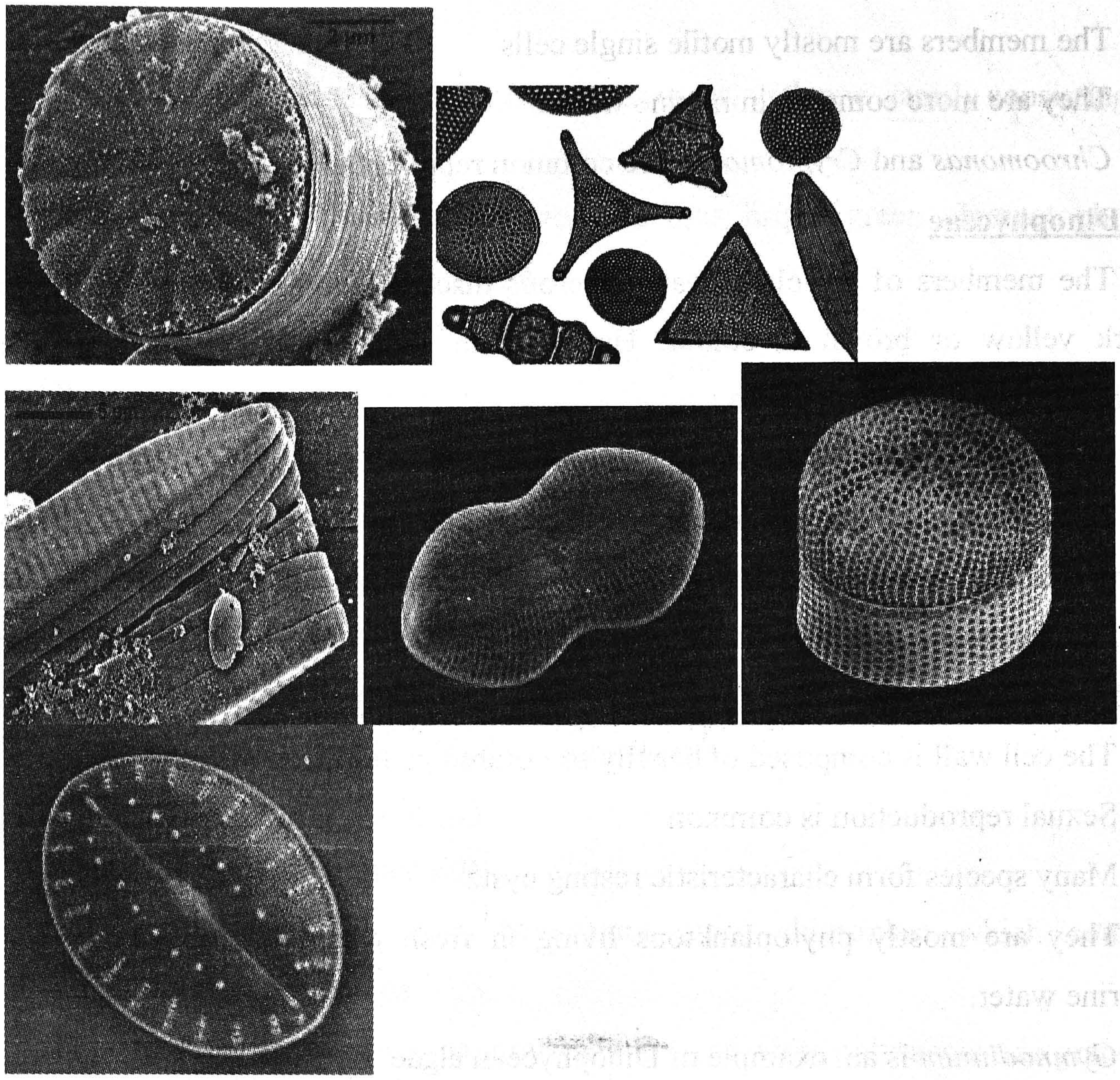


Figure-10

5. Chryptophyceae

This class includes two orders, namely Cryptomonadales and Cryptococcales.

The members of the class usually bear two parietal chromatophores with various colours. The cells may be red, blue, olive yellow, brown or green because of various proportions of chlorophyll-a and c. β -carotene, diatoxanthin and biliproteins in their chromatophores.

Pyrenoids may be present

The storage products are starch and oil.The motile cells have two slightly unequal flagella at their anterior ends.

Reproduction is mostly by longitudinal cell division and cyst formation

Sexual reproduction is rare. It is isogamous, if present.

The members are mostly motile single cells

They are more common in marine waster

Chroomonas and *Cryptomonas* are common representatives of Chrysophyceae

6. Dinophyceae

The members of the class bear numerous discoid chromatophores which are dark yellow or brown in colour. However, in some saprophytic species the chromatophores are colourless.

The storage products are starch and oil.

The members are mostly motile single cells. The motile cell has one transverse furrow and a longitudinal furrow. A flagellum arises from the transverse furrow and encircles the cell, and another flagellum arises from the longitudinal furrow and faces backwards.

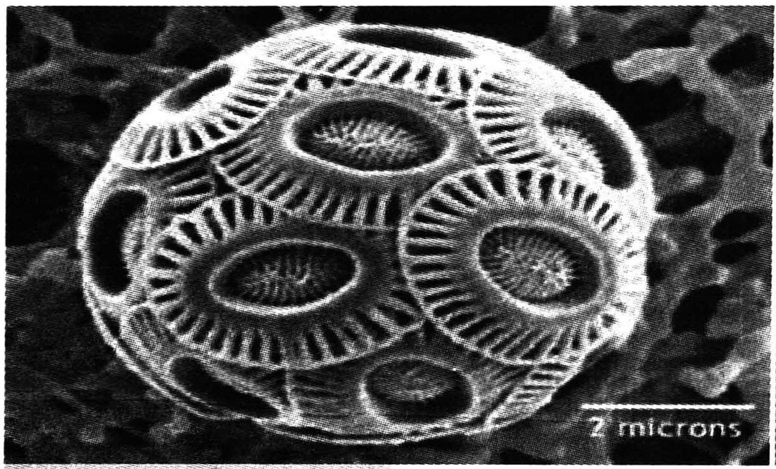
The cell wall is composed of heavily sculptured plates made of cellulose

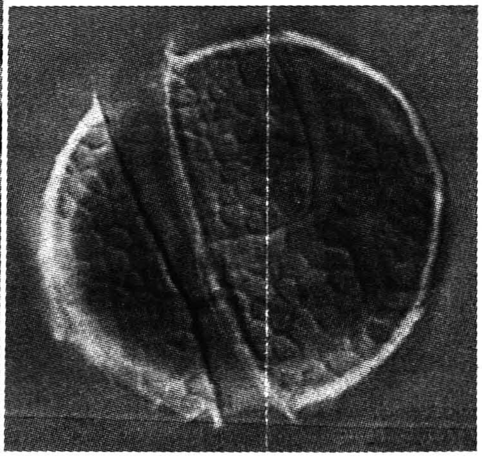
Sexual reproduction is common

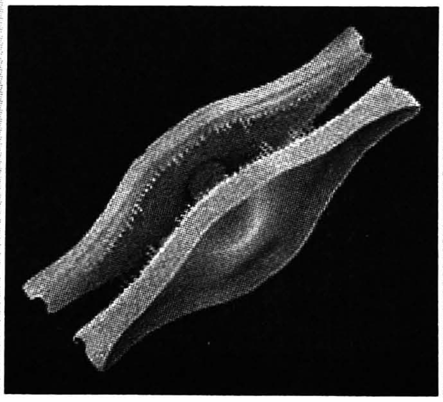
Many species form characteristic resting cysts

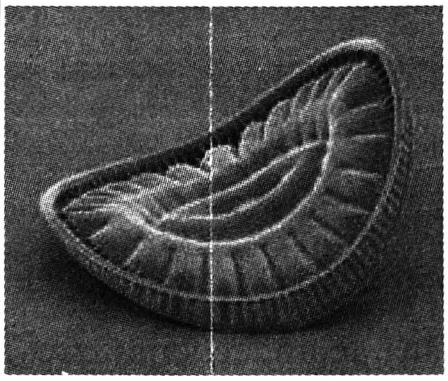
They are mostly phytoplanktons living in fresh water, brackish water and marine water.

Gymnodinium is an example of Dinophycean algae.









7. Chloromonadineae:

This is the smallest class consisting of one order, with one family consisting of a few generas.

The members of the class contain numerous bright green chromatophores which contain excess of xanthophylls

Pyrenoids are absent

Reserve foods are stored as oil

The motile cells bear two equal flagella, inserted apically in a slight depression.

Reproduction is mainly by longitudinal division of individuals

Sexual reproduction is rare. It is isogamous, if present.

Most of the species inhabit fresh water.

Trentonia is an example of Chloromonadineae.

8.Euglenineae(Euglenophyceae)

This class is called Euglenoids.

The members of this class have pure green chloroplast which contain chlorophylls and carotenoids

Food reserves are stored as paramylon, a form of white polysaccharide granule

Almost all members are flagellates and unicellular. They have one or two flagella inserted in a canal-like invagination at their front end.

Pyrenoids are often well-developed

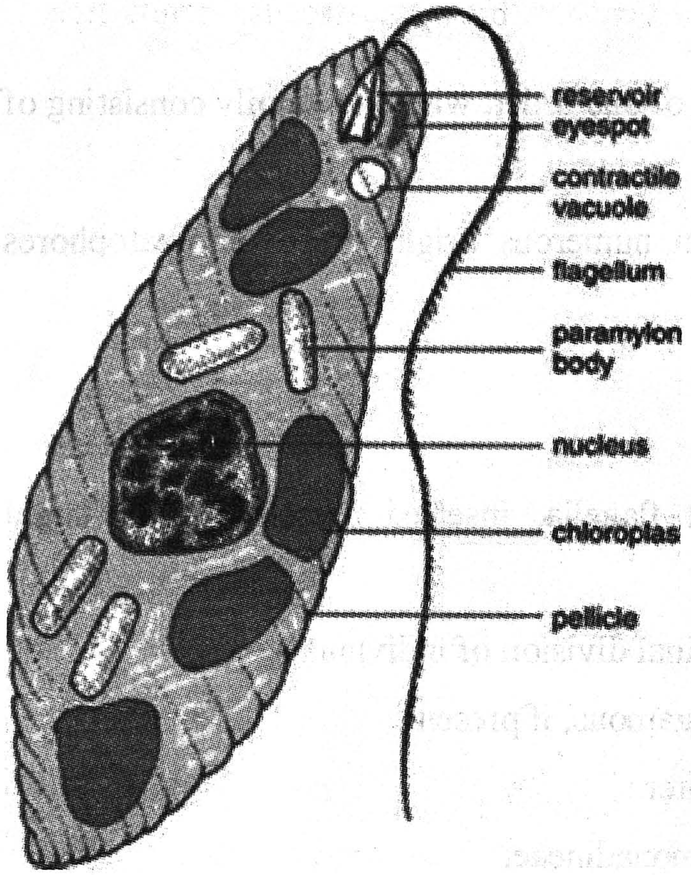
The resting cysts are covered by mucilage

Reproduction is by longitudinal fission of individual cells.

Most cases are flagellated unicellular forms

This class is restricted to fresh water

Euglena, Eutreptia, Astasia, ect. are common representatives of Euglenineae.



9. Phaeophyceae

The members of this class are called brown algae. Phaeophyceae includes 9 orders, namely Ectocarpales, Tilopteridales, Cutleriales, Sporochnales, Desmarestiales, Laminarials, Sphacelariales, Dictyotales and Fucales.

The members of this class have brown coloured chromatophores which contain excess of fucoxanthin and small proportion of chlorophyll-a and c, and carotenoids

Food reserves are stored as alcohols, mannitol and laminarin. Rarely oils or fucosan granules

In majority of the cases, the cells contain fucosan vesicles

The motile reproductive cells possess two lateral flagella, of which one faces upwards and the other faces downwards.

The cell wall is made of cellulose, fucinic acid and alginic acid

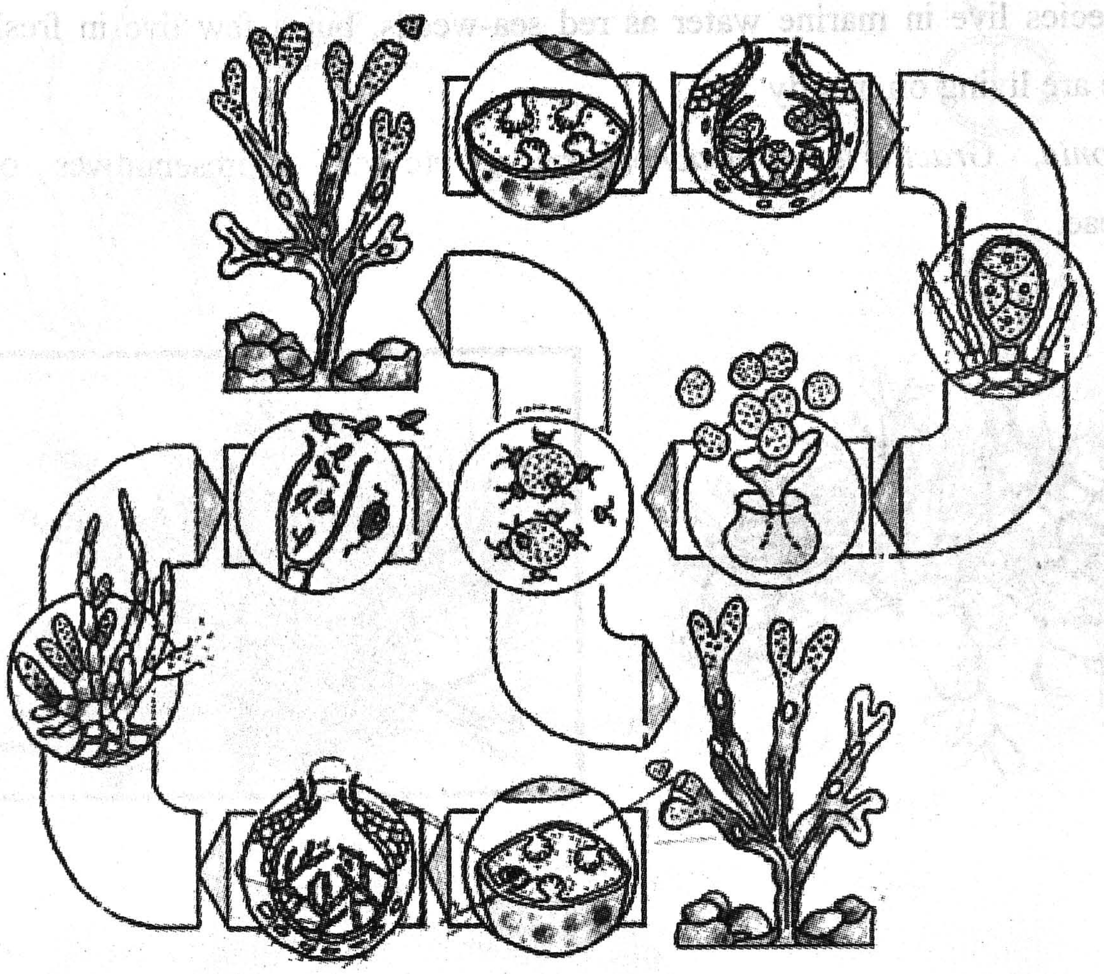
Sexual reproduction is very common, and it varies from isogamy to oogamy

The zygote exhibits no resting period

The thallus may be heterotrichous filaments or pseudo-parenchymatous filaments or true parenchymatous filaments.

Most of the members live in marine water as brown seaweeds. A few live in fresh water

Sargassum, Dictyota, Fucus, Macrocystis, Laminaria, etc are common representatives of phaeophyceae.



10. Rhodophyceae

The members of this class are called red algae. Rhodophyceae includes 7 orders, namely Bangiales, Nemalionales, Gelidiales, Cryptonemiales, Gigartinales, Rhodymenials and Ceramiales.

The members of the class have red colour chromatophores which contain excess of phycoerythrin and small amount of chlorophylls, carotenoids and xanthophylls

Pyrenoids are present in lower forms

Food reserves are stored as floridean starch , galactan sulfate and floridosides

Motile reproductive cells and flagellated members are not known

The cell wall is made of polysaccharides and polyuronic acids

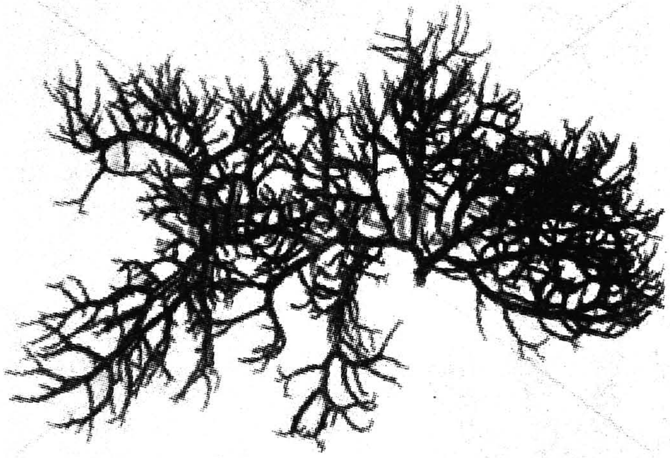
Asexual and sexual reproductions are common. Sexual reproduction is mainly of oogamous type. After fertilization many branches of female sex organs fuse

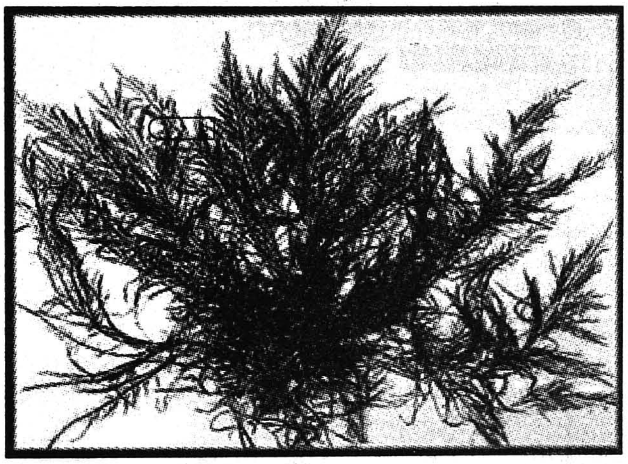
together and produce a cluster of carpospores. This phenomenon is called post fertilization change

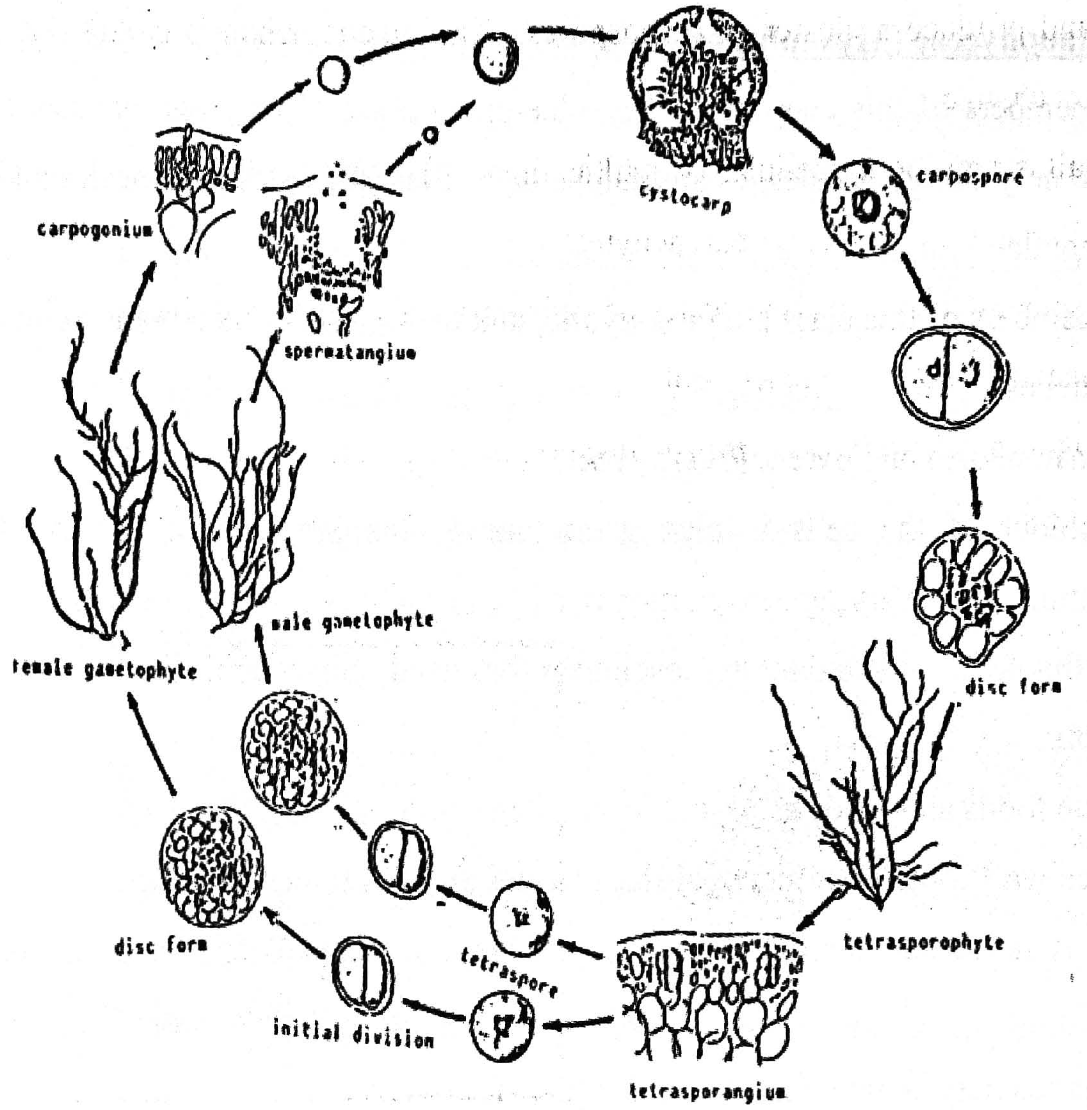
The thallus may be unicellular or multicellular. The multicellular forms may be either filamentous or pseudo-parenchymatous

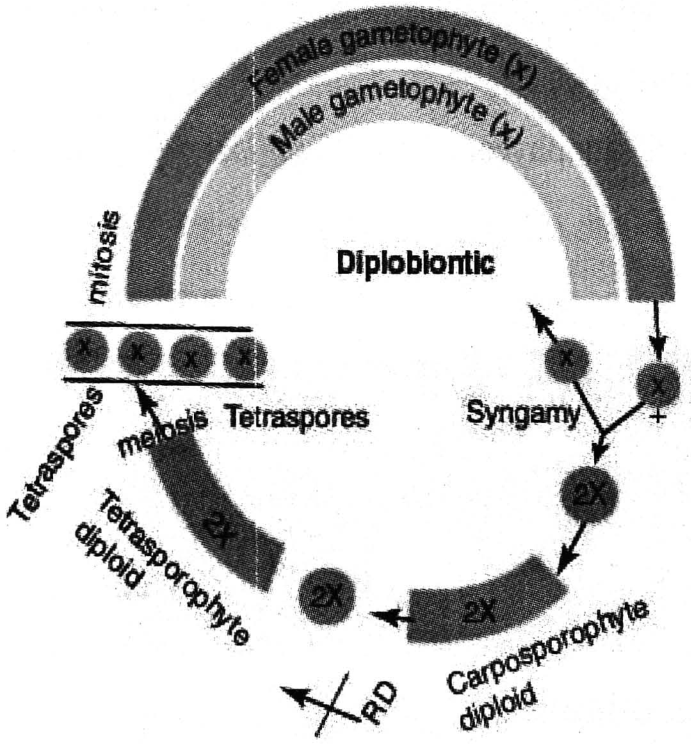
Many species live in marine water as red sea-weeds, but a few live in fresh water. Some are living on muddy soil.

Polysiphonia, Gracilaria, Batrachospermum etc are representatives of Rhodophyceae.






carpogonium
spermatangium
cystocarp
carpospore
disc form
female gametophyte
male gametophyte
disc form
tetrasporophyte
tetraspore
initial division
tetrasporangium


Female gametophyte (x)
Male gametophyte (x)
Diplobiontic
mitosis
Tetraspores
meiosis
Tetraspores
Syngamy
Tetrasporophyte
diploid
2X
Carposporophyte
diploid
RD

11. Cyanaophyceae (Myxophyceae)

The members of this class are called blue-green algae. This class includes 5 orders, namely Chroococcales, Chamaesiphonales, Pleurocarpales, Nostocales and Stigonematales.

The members of this class are prokaryotic, and do not posses membrane bound cell organelles

Chromatophores and pyrenoids are absent

The colour of the cells is blue green due to the presence of excess of phycocyanin and varying proportions of chlorophyll-a, β-carotene, , myxoxanthophyll, myxoxanthin, oscillaxanthin and phycoerythrin in their protoplasm.

Reserve foods are stored as sugars (cyanophycean starch) and glycogen

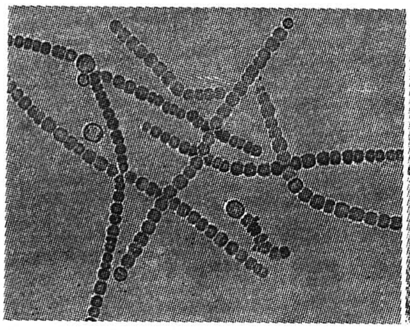
The cell wall consists of mucopolysaccharides and gelatinous envelop

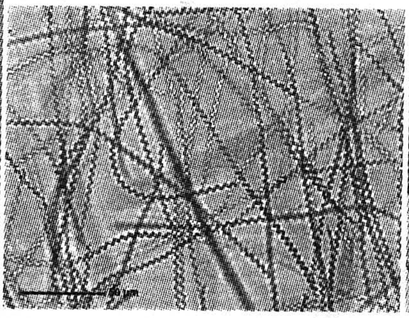
There is no sexual reproduction. Vegetative and asexual reproductions are common

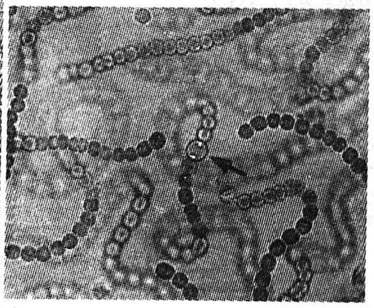
The thallus may be unicellular or colonial or filamentous.

The members of the class are widely distributed in fresh water and moist soils. But some species live in sea water also

Common representatives of Cyanophyceae are *Oscillatoria* , *Nostoc, Gloeocapsa, Scytonema, etc.*







Merits and Demerits of Fritsch classification:

Fritsch distinguished clearly eleven classes of the algae and regarded algae as one group or one division. This classification is not considered to be a natural one but is based on the phylogeny and interrelationships. Somehow, it is quite efficient and clearly maintains the widely recognized valid distribution of classes, orders

and families. Though, in the later period, phycologists separated blue green algae (Cyanophyceae) and ranked them to a separate division (Cyanobacteria) because of various characters not observed in the remaining algae.

Fritsch included Siphonales under the class Chlorophyceae based on typical Chlorophycean characters. While Chapman has placed some Siphonales under Xanthophyceae because of the following characters.

1. Presence of larger quantities of xanthophylls
2. Chloroplasts and pyrenoids, characteristics of chlorophyceae are absent.
3. Reserve food material is oil and not the starch
4. Flagella are heterokont not isokont.

Likewise, Fritsch included members of Charales under Chlorophyceae due to following characters.

1. Plants haploid
2. Chlorophyll as the predominant pigment.
3.Presence of nodes and internodes and braches of limited and unlimited growth, a feature similar to Draparnaldiopsis (a member of Chaeatophorales-green algae).

However, Chapman separated Charales from Chlorophyceae and raised them to the rank of a class. This separation was based on the presence of following characters in charales.

1. Complex structure of vegetative thallus
2. Structure of reproductive organs.
3. The occurrence of protonemal stage in the life history.

SALIENT FEATURES OF CYANOPHYTA, CHLOROHPYTA, BACILLARIOPHYTA, PHAEOPHYTA AND RHODOPHYTA:

Cyanophyta:

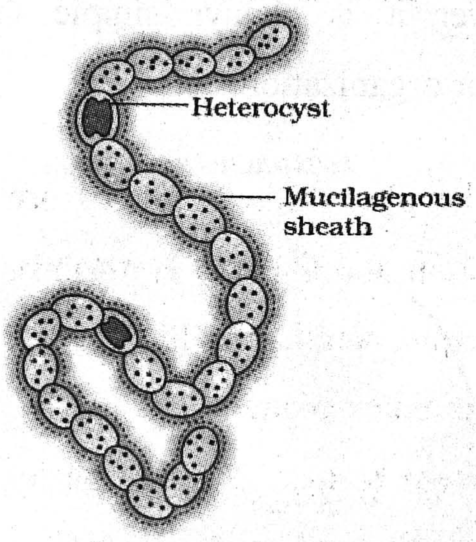
1. The members of Cyanophyta are simple, primitive and ancient group of the plant kingdom. Thallus is the simplest, microscopic and oxygen producing low state of the thallus organization .This division includes the blue-green algae in a single class Cyanophyceae or Myxophyceae comprising 2,500 species under 150 genera.

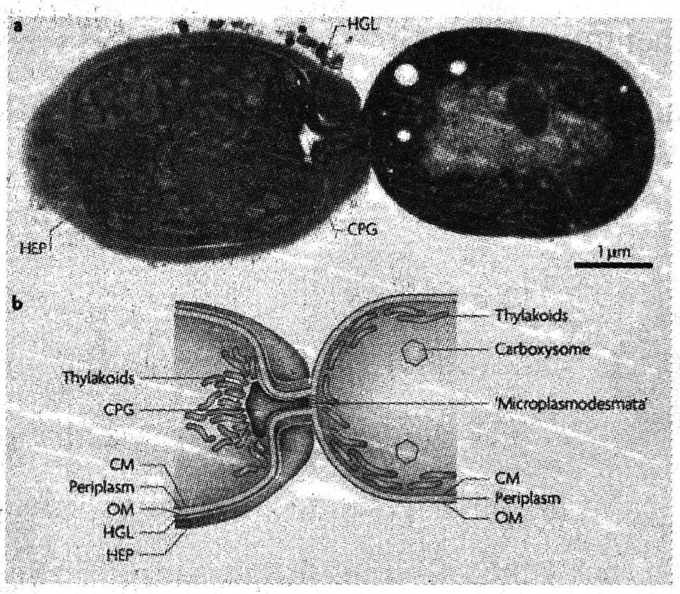
2. More or less unstable condition of the cell wall (similar to Gram –ve bacteria)
3. Absence of a definitely organized nucleus. It lacks the nuclear membrane and nucleoli. (Procaryotic).
4. Simple protoplast without any plastids, endoplasmic reticulum, mitochondria, golgi apparatus and sap cavity.
5. Abundant secretion of pectin by the protoplast.
6. Membrane bound Chloroplasts are absent. The phycobilin pigments are unique to this calss. They are blue C-phycocyanin and C phycoerythrin in addition to Chlorophyll-a, B-carotene and unique, xanthophylls, namely, myxoxanthin . The blue phycocyanin-c as the dominant pigment.

1. 7.Absence of sex organs and motile reproductive bodies. Propagation by vegetative means (fission, fragmentation, hormogones and endospores)

7. Total lack of sexual reproduction. However genetic recombination has been observed but the mechanism is unknown
8. Propagation entirely by vegetative means (fission, fragmentation, etc.) and sometimes by spores.
9. Very little or no differentiation or specialisation among the cells constituting the thallus.
10. Charcteristic blue green coloration of the thallus which varies greatly in shade.
11. Product of photosynthesis a unique kind of starch, the cyanophycean starch resembling glycogen.
12. The division of the protoplast by the formation of a cytoplasmic plate followed by a ring-like in growth of the septum arising from the cell wall.
13. Absence of motile flagellated stages.
14. Locomotion is present. It is gliding or jerky type.
15. Many filamentous blue-green algae possess specialized cells called Heterocysts for nitrogen fixation.

16. Occurrence in the pre-paleozoic period. The imprints on the two billion years old rocks of the Archaeozoic era resemble the present-day blue-green algae.



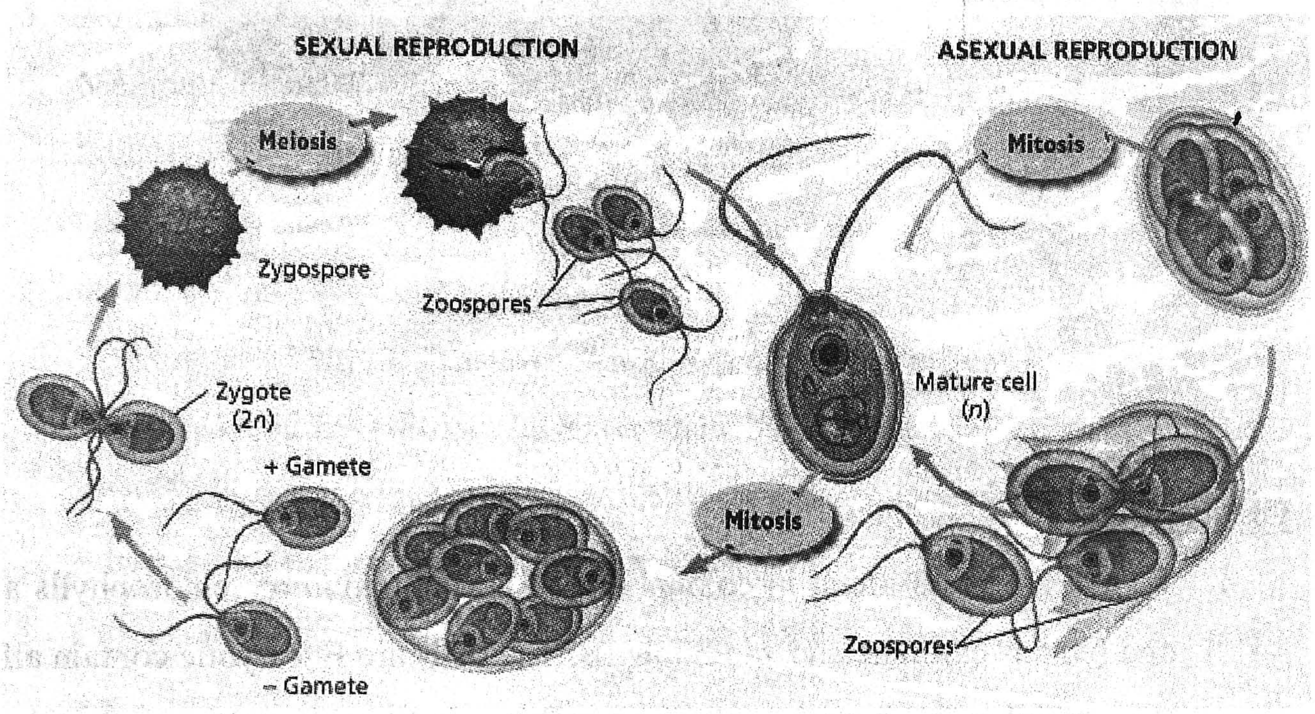


Chlorophyta:

1. 1.They are grass green in colour due to accumulation of chlorophylls a and b over carotene and xanthophylls. The cells are Eucaryotic contain all the membrane bound cell organelles such as nucleus, plastids, mitochondria, dictyosomes, endoplasmic reticulum the true vesicles.
2. The pigments are localized in the green plastids known as chloroplasts.
3. The reserve carbohydrate food is stored as starch.
4. The chloroplasts contain the pyrenoids with starch sheath
5. The cell has a well defined nucleus and in the higher forms a central sap cavity in addition.
6. The cell wall is stable and contains cellulose.
7. The majority produce motile reproductive cells which may be bi or quadriflagellate rarely with a ring of flagella as in the Oedogoniales. The flagella are of equal length and of whiplash type inserted at the anterior end. The motile cells contains eyespot or stigma.
8. Sexual reproduction ranges from isogamy to oogamy. The zygote nearly always enters upon the resting period
9. The sex organs are always unicellular.

10. Zygote generally is the only diploid structure in the life cycle.

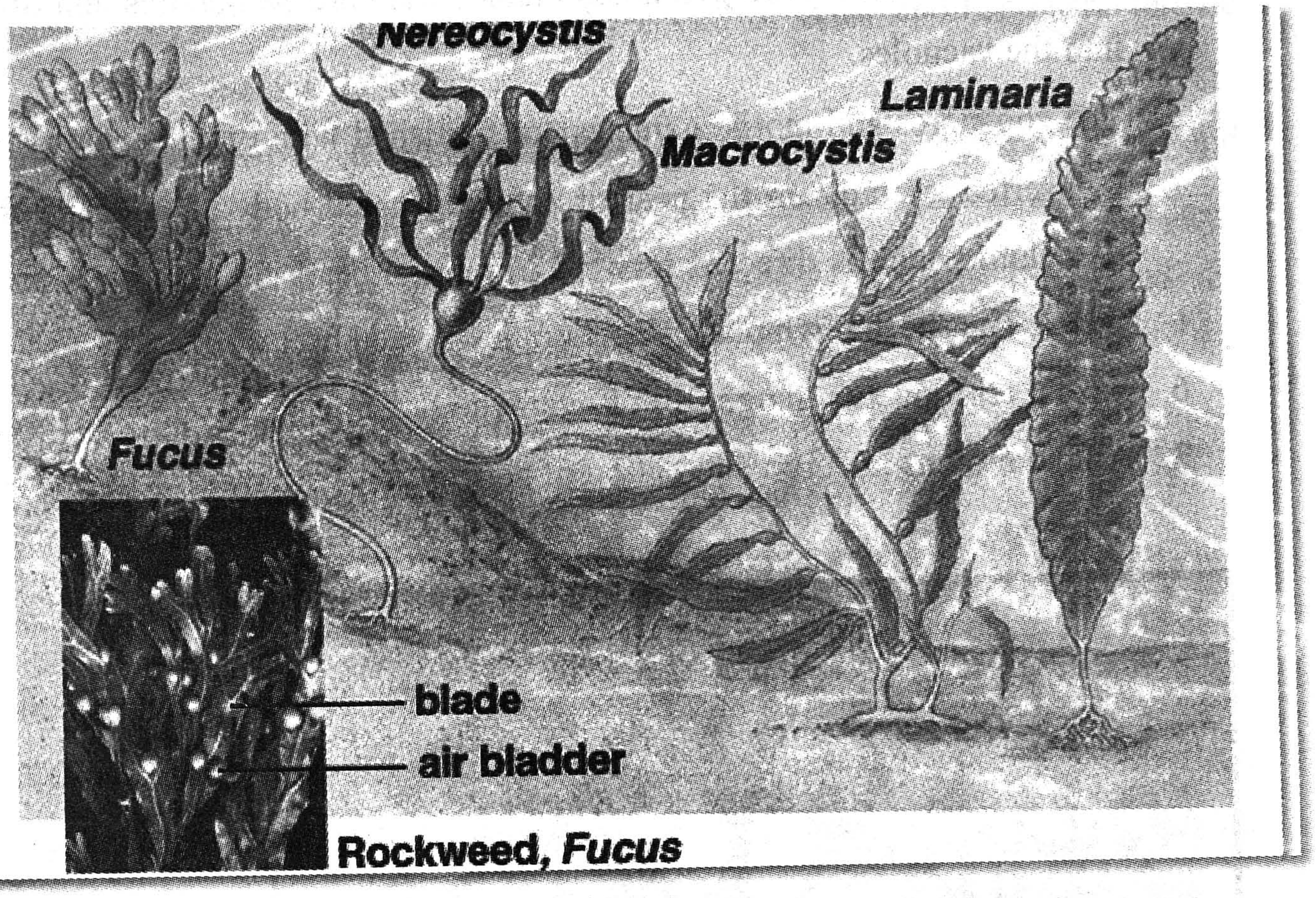
11. The plant body is unicellular or multicellular. The former may be solitary or colonial. The multicellular forms show a considerable range of variation in the form and structure of the plant body. Commonly they are filamentous, sometimes massive. However it is always simple in construction and shows relatively little cellular organization.



Bacillariophyta: (Diatoms)

1. They are found in both fresh and salt water. Microscopic-single celled but in some the cells are united into colonies.
2. Cell wall is made up of Silica with beutifull ornamentations. It is called shell or frustule. Frustule is made up of two overlapping halves. The overlapping side walls of the two halves are called the girdles.
3. Photosynthetic pigments are Chlorphyll a and c. The xanthophyll pigment is called fucoxanthin .
4. The reserve food material is callled Volutine and oil.
5. Cells are diploid. Reproduction is by Oogamous type of sexual reproduction. As result diploid zygote is formed. It is called Auxospore.

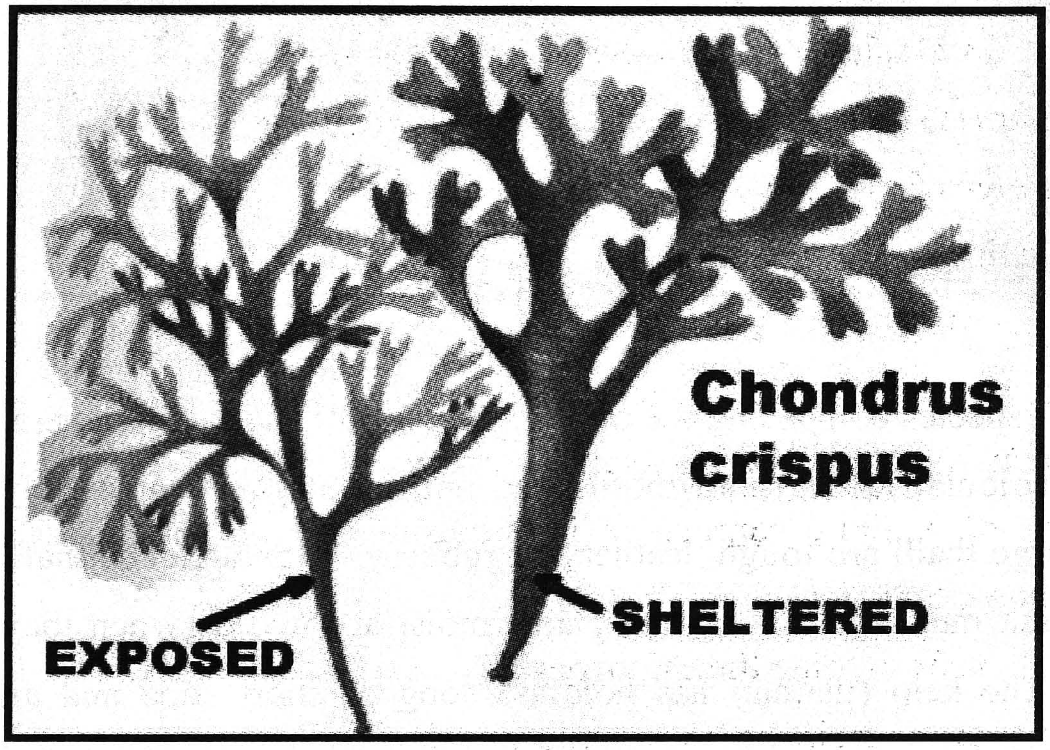
Diversification among brown algae



Phaeophyta:

1. The number of species composing the calss is over 1,500 under 250 genera. Unicells and colonial forms (both motile and non motile) are completely absent. The large thalli are tough, leathery or rubbery in texture. The thalli secrete abundant mucilage to keep the plants moist at low tide when they are exposed. The kelp (thallus) has holdfast, long or short stipe and an expanded blade..
2. The cells are uninucleate and the cell wall contains a gel-like polysaccharide <u>algin</u> and the carbohydrate <u>Fucoidin.</u> The presence of fucosan vesicles in the cells is another characteristic.
3. The photosynthetic pigments in the chromatophore are chlorophyll a and little <u>chlorophyll c</u> but no chlorophyll b, β –carotein and xanthophylls such as <u>fucoxanthin</u> and <u>diatoxanthin.</u> The fucoxianthin masks the other pigments.

4. The reserve food is so stored in the form of mannitol, laminarin and oil. They are formed in the pyrenoids outside the chromatophores and diffuse into the vacuoles.
5. The zoospores and motile gametes are furnished with two unequal flagella is inserted laterally on the pear or spindle shaped body. The longer tinsel flagellum which is directed forward in motion bears flimmer hairs on two sides. The shorter whiplash flagellum is directed backwards
6. Sexual reproduction range from isogamy to oogamy.
7. All the browns undergo alternation of generations with meiosis during spore formation.



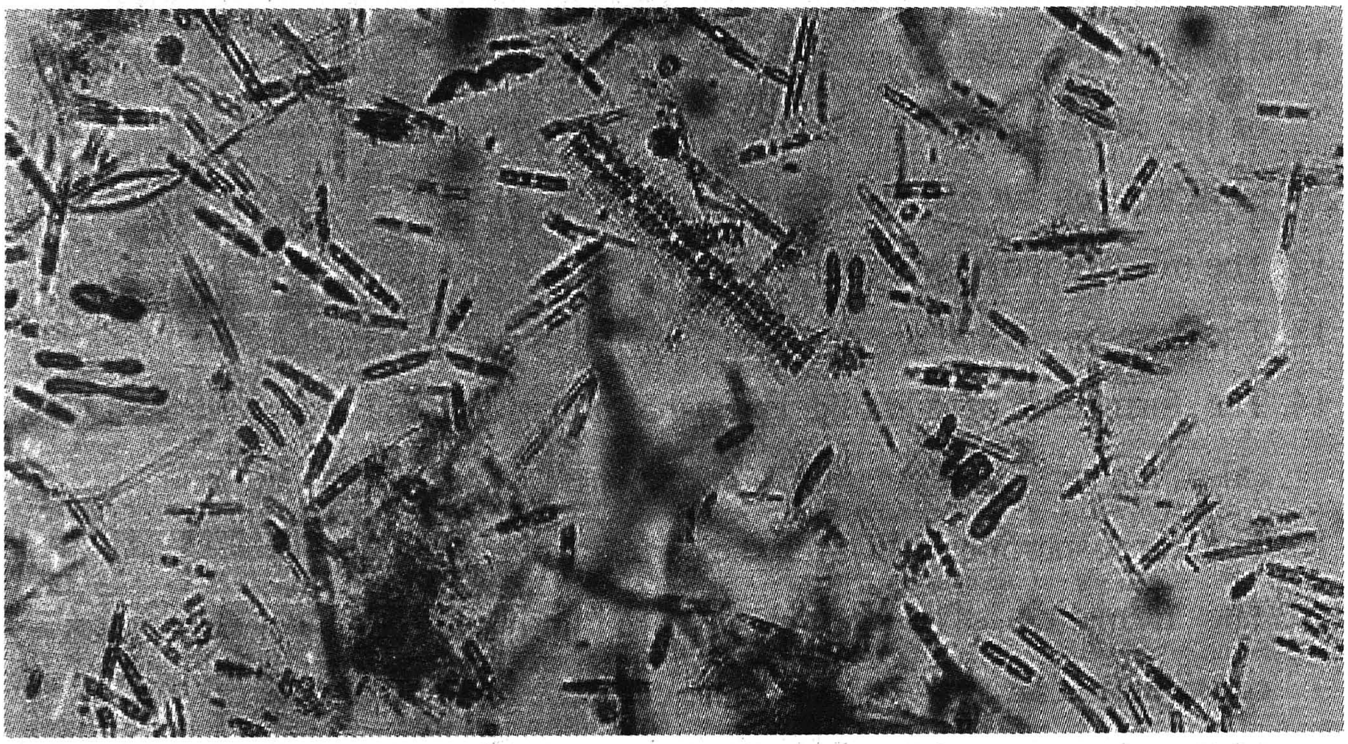
Rhodophyta:

1. The red seaweeds are marine habitat. They are 5,250 species under 830 generra. The polysiphonous nature of the thallus which consists of an axial siphon surrounded by a number of pericentral siphons.
2. The plant body consisting of the prostrate and erect portion.
3. The feathery,upright portion consisting of a much branched system of relatively large branches bearing numerous small branches called the trichoblasts. The latter bear the sex organs.
4. Growth in length by means of a single, dome-shaped apical cell.

5. Occurrence of pit connections between the adjoining central cells and between the central cells and the pericentral cells, another characteristic feature of the red algae.
6. Occurrence of three kinds of plants –gametophytes, carposporophyte and tetrasporophyte.
7. Sexual reproduction is oogamous. The male sex organs are called the spermatangia and the female crapogonia.
8. The spermatangia are developed in large numbers on the male trichoblast. The male gamete or the spermatium is non-motile.
9. The carpogonium is a flask-shaped structure consisting of the basal swollen portion and the distal tubular portion-the trichogyne.
10. The carpogonium is situated on the carpogonium filament or procarp.
11. The diploid nucleus formed by fertilization lies at the basal swollen portion of the carpogonium. Latter migrate in to the tubular connection to the auxiliary cell cut off from the supporting cells.
12. The migration of one of the diploid nuclei into the auxiliary cell.
13. The development of gonimoblast filaments from the auxiliary cell.
14. The formation of a diplid carpospore in the gonimoblast filament now called the carposoporangium.
15. The carposporophyte bearing the carpospores.
16. The formation of a fruit body or fructification called the cystocarp consisting of an cup-shaped sheath containing the carpospores.
1. 17.Development of the tetrasporophyte by the germination of the diploid carposproe.
17. The tetrsporophyte produce tetraspores by meiosis.
18. Meiosis occurs at the time of the differentiation of tetraspores which are thus haploid.
19. Germination of haploid tetraspores to give rise to the male and female gametophyte
20. Distinct alternation of generations consisting of morphologically alike sexual and asexual plants.

ECOLOGICAL SIGNIFICANCE

Snow and ice Algae: Algae found in snow give a distinctive colouration to snow, "red snow" and "green snow". The colour may be due to the excess amount of carotenoid pigments or chlorophyll pigments in the stages of life cycle. The characteristic of snow algae is that they are able to withstand very low temperatures. These algae occur on the surface of snow. Some snow algae are recorded up to 30 cm depth in snow. Since light penetration occurs up to 50 cm, photosynthesis by these algae is possible. However CO_2 fixation efficiency of these snow algae is low in comparison to warm water algae. Red snow algae include *Chlorosphaera Antarctica, Scotiella antarctica* and *Raphidonema nivale.* Green snow algae are *Chlamydomonas nivalis, Chlorosphaera antarctica* and *Raphidonema nivale*



Algae of hot springs (Thermal springs): Hot springs temperature range from 40°C to 75 °C. Hot springs enrich with some inorganic ions including potassium, sodium, carbonate, silicate, sulphide, sulphate and chloride. The common blue green algae of such habitats are *Phormidium laminosum, Mastigocladus laminosus* and *Synechococcus lividus.* These algae have thermal tolerance up to 75 °C. Some diatoms can grow in hot springs up to 50 °C and few Chlorophytes up to 48 °C.

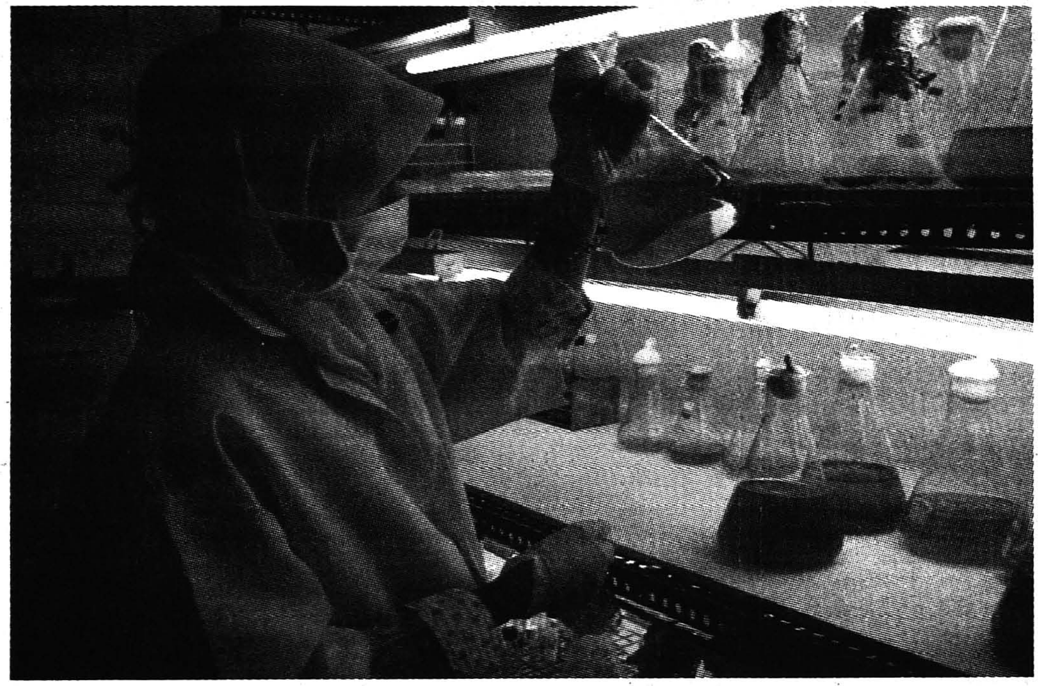
Desert algae: Deserts are characterized by lack of moisture and high aridity, desiccation of soil due to high temperatures and exposure to solar radiation over prolonged periods. These factors make a desert an extreme habitat. Some blue green algae and certain Chemoautotrophic bacteria were the organisms found in such desiccated habitats. Some of them can be completely desiccated at near 100 ^{o}C due to their water potential capacity and then revive on access to moisture. Blue green algae commonly found in desert soils include, *Nostoc muscorum, Scytonema hoffmanni* and *Schizothrix calcicola.*

Hypersaline habitat: Hypersaline habitat is found in the crystallisers of salt pans near Tuticorine. The salinity of the water in these pans is much higher than that of normal seawater, reaching up to 24 % in the crystalliser pans. The halotolerant algae include blue green algae such as *Aphanothece* spp.,*Oscillatoria* spp., and *Phormidium* spp. and the green alga *Dunaliella* spp.,. They have adaptive morphological features such as copious mucilage around the trichomes (filaments) or in the colony matrix. β-Carotene content of the cells also show variation with salinity. Glycerol level is also increased under salt stress as a protective device.

Endophytism: Endophytic algae occur in all groups of plants. *Nostoc sphaericum* occur endophytically in cavities in the thallus of *Anthoceros*, a Bryophyte. *Anabaena azollae* is endophytic in the fronds of *Azolla,* a water fern and has been recommended as a biofertilizer in rice fields for its N_2 fixing ability. The corolloid roots of *Cycas,* a gymnosperm is with blue green alga forming a distinct zone in

the cortex. Among angiosperms, *Gunnera* is known to harbour a *Nostoc* species as an endophyte. The marine microalga, *Sheblonema* sp. is exist as endophytes in other marine algae such as *Gelidium* and *Grateloupia.* Indicator organism is defined as the any member of the flora or fauna of a habitat and any species may be considered as a potential indicator organism. Bacteria, Algae, Macrophytes, Protozoa, Macro invertebrates and Fishes are used as an indicator organism.

ALGAL BIOINDICATORS



Bioindicator species must satisfy the following:

a) Species should be present throughout and in abundance

b) Each taxon should have precise ecological limits or ranges

c) That the ranges can be defined

d) That the taxon can easily be identified

e) That the reliable identification requires high degree of expertise.

Algae serve as very good bioindicators in assessing the quality of water. Kolkwitz and Marsson (1909) were the first to describe changes in algal composition of river water induced by pollution. They identified several zones in water with varying degrees of pollution and corresponding change in algal flora. According to them, there are three zones in a polluted river, each zone having its characteristic algal flora. Three zones are:

1.Polysaprobic zone: Oxygen is deficient; high content of decomposable organic matter *Euglena* and *Oscillatoria* are rarely present in this zone.

2. Mesosaprobic zone: A little quantity of O_2 is available; Organic waste also less. Algae like *Oscillatoria, Ulothirix* and *Phormidium* grow in this zone.

3.Oligosaprobic Zone: It is opposite of polysaprobic zone. There is little or no decomposable organic matter. The water is rich in O_2 and allows the growth of algae like *Cladophora, Calothrix, Batrachospermum* and *Meridian.*

Patrick (1977) has proposed nine zonation. According to him diatoms are best suited to be the algal indicators of water pollution. The Coprozoic zone is the most polluted and the Katharobic zone is the least polluted. They are

1. Coprozoic zone Bacteria
2. Polysaprobic zone I *Euglena,*
3. Polysaprobic zone II *Thiothrix*
4. Polysaprobic zone III *Oscillatoria*
5. Mesosaprobic zone I *Ulothrix,*
6. Mesosaprobic zone II *Cladophora,*
7. Mesosaprobic zone IIII *Lemanea,*
8. Oligosaprobic zone: *Vaucheria,*
9. Katharobic zone: *Calothrix*

Venkateswarlu and Manikya Reddy (1977) divided water quality into Five types based on the presence of Cyanophyceae, Chlorophyceae, Euglenophyceae and diatoms.

1. Pure water:- Diatoms: *Synedra ,Cymbella & Achnanthes.*
2. Highly sensitive to pollution: - Chlorophyceae: Desmids
3. Oligotrophic clear water: - Cyanophyceae: *Nostoc, Calothrix & Scytonema*
4. Eutrophic –highly organically polluted & high concentration of nitrogenous materials: -

   Diatoms: *Nitzschia & Navicula*
5. Dirty water-high levels of heavy metals, chemical effluents with toxic effect:-

   Chlorophyceae:*Chlamydomonas botryopora, Zygnema, Spirogyra*

   Cyanophyceae: *Microcystis aeruginosa, Anabaena flos-aquae*

Bioremediation of heavy metals using Sea weeds

Industrial wastewaters are a major source of heavy metal pollution. They pose a serious threat to the environment and man as the metal ions accumulate in the food chain. Current technologies for the treatment of heavy metal contamination are either costly or ineffective. The current methods are precipitation, ion - exchange and electrolytic techniques. Precipitation methods are inexpensive but

ineffective. Ion-exchange resins are expensive but are effective. Electrolysis is advanced technique but relies on electricity. Thus there is a need to develop alternative low-cost, environment-friendly technologies to remove metal ions from effluent.

New biotechnology method is based on the sorption of dissolved metals by organic biomass for the concentration, removal and recovery of heavy metals from wastewater. This process is called 'biosorption'. Biosorption allows recovery of the heavy metal ions. Dead biomasses also show more effective biosorption than living cells.

Some biosorbents have a broad-range binding capacity while others are more specific for certain types of metals. The biosorption behavior depends on its cell wall composition, ion exchange, chelation, adsorption by physical forces, ion entrapment in inter- and intra-capillaries, spaces of the structural polysaccharide network, the concentration gradient through cell walls and membranes. Biosorption proceeds in two phases. The initial fast reaction is based on anion exchange. The second slower phase is due to the diffusion of ions into the cell structures.

The biosorption reactions are advantageous for application purposes. The factors affecting biosorption are pH, biomass concentration, agitation, and composition of ion solution and particle size.

Examples of biomasses are bacteria, yeasts, fungi, micro algae, macro algae and agricultural products such as wool, rice, straw and coconut husks. Biomass from fermentation process also provides a biomass.

Two biosorbents are available commercially. They are AlgaSORB™ made from *Chlorella vulgaris* and AMT-BIOCLAIM™ with a *Bacillus* biomass. These are able to reduce metal ion concentration.

Seaweeds are also as an inexpensive and readily available source of biomass harvested either from natural sources or industrial waste by-products. Seaweeds are known to accumulate heavy metals. They are also used as bioindicators of pollution in many environmental assessment studies and have proven as a promising biosorbents because of their polysaccharide nature of their cell walls.

Many biosorption studies have investigated with the large brown algae and their derived products as biosorbents. Heavy metal biosorption by three kelps (*Ecklonia maxima, Lessonia flavicans and Durvillea potatorum*) as well as alginate fiber and 'dealginate', the seaweed waste product from the production of alginate have been investigated. Alginate fiber gave the best results than the seaweed material. The seaweed biomasses were found to perform better than the commercial resin with 73% of uptake occurring within the first 3 min. The biosorption ability of the brown algae *Ascophyllum nodosum, Fucus vesiculosus* and *Sargassum natans* has been compared to a commercial ion-exchange resin. The use of $CaCl_2$ to pretreat *Padina sp.* for the adsorption of Cu was also successful, with 90% uptake occurring within 15 min. The waste product from alginate extraction of *Sargassum sp.* was cross-linked using polyethleneimine resin and glutaraldehyde. This also an effective biosorbent for industrial scale.

Once the heavy metals are concentrated on the biomass, it is possible to recover the metal and regenerate by repeated adsorption-desorption cycles. The broad range and high capacity for heavy metal recovery suggests that certain brown seaweeds and their derived products are useful to industrial wastewater treatment on a larger scale.

ECONOMIC IMPORTANCE OF ALGAE

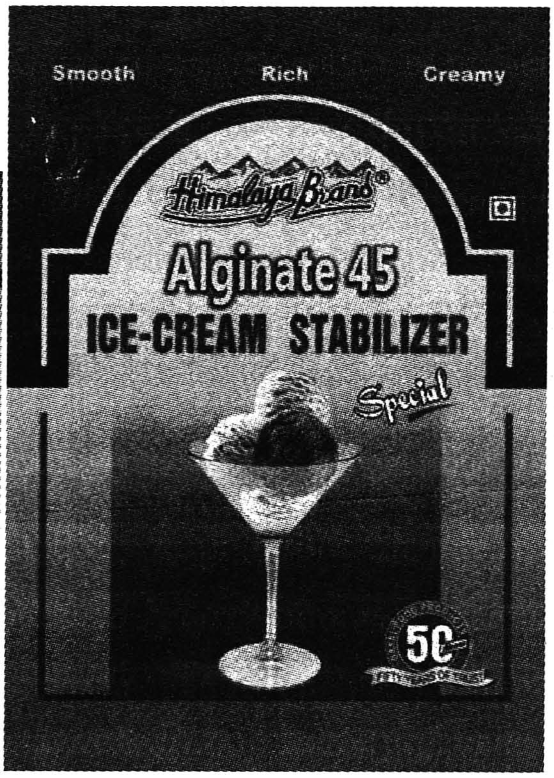
Algae are important in the fields of agriculture and industry. In addition they are used as food, fodder and as manure

Role in Industry: The algae are useful as the source of many commercial products. The four major products derived commercially from them are agar-agar, carrageenin, alginic acid and diatomite

1.Agar-agar: It is cell wall carbohydrate produced by red algae. The main sources of agar is *Gelidium, Gracilaria* and *Gigartina*. It is used as a base for culture media for bacteria, fungi, algae and in tissue culture. It is used in the preparation of certain medicines and cosmetics and in leather and textile industries. It is largely used as a laxative and in baked goods, meat industry and as an emulsifier in dairy products

2.Carrageenin: It is a cell wall mucilaginous extract. The source is a red alga *Chondrus crispus* (Irish moss). Carrageenin is used in food, textile, pharmaceutical and leather industries. It is also used as remedy for cough. It is used as a component of toothpastes, deodorants, and cosmetics and in paints.

3.Alginic acid: Algin is a carbohydrate. It occurs in the walls of the brown seaweeds like *Ascophyllum, Laminaria, Macrocystis* and *Padina*. The salts of alginic acid found in the cell walls. They are called alginates. The alginates are used as thickeners in food industry, cosmetics and in textile industry as printing pastes. They are used in the production of artificial fibers. They are also used in the rubber industry. The alginates are also used as emulsifiers, as gelling agents in confectionary, dental impression, face powers, paints and in ice creams.



4. Diatomite: It is a rock-like deposit formed from the dead cell walls of the diatoms. These diatomaceous deposits are mined in several parts of the world. It is a whitish substance, soft and light. It is highly porous and insoluble. It has abrasive qualities and is chemically inert. It is fore proof. It is used as a filter in oil and sugar industry. It is also used in refrigerators, boilers, hot and cold pipes and in brick making for construction of constant temperature rooms, sound proof rooms. It is also used in toothpaste, bleaching powder and in silver polish.

5.Minerals: Soda Potash and Iodine are extracted from brown seaweeds. The red alga *Polysiphonia* is the source of Bromine. Glue is extracted from some red algae. It is used for sizing paper and cloth. It is also used as an adhesive.

Role in Agriculture: Blue-green algae are capable of fixing atmospheric nitrogen. It improves the growth of crop plants. Blue-green algae re the chief agents for nitrogen fixation in rice fields. They increase the fertility of the soil by fixing atmospheric nitrogen. Some of the important nitrogen fixing blue-green algae is *Gloeothece, Oscillatoria, Spirulina, Anabaena* and *Nostoc* .They increase the nitrogen content of the soil. Seaweeds are used as manure to the farmland near the coastal regions. Large brown and red algae are used as organic fertilizers. In the Japan they are used in the rice fields whereas in China for groundnuts and sweet potatoes. In India *Padina* is used as a fertilizer around coconut trees. Liquid extracts of seaweeds are sold as liquid fertilizers and also as insecticides. The seaweed products aid in binding sandy soils. They also help to break down clayey soils and thus promote a good aeration and permeability. In Germany, seaweeds are mixed with cement, and the mixture is used for making lightweight buildings. In some countries some red algae are used in the place of lime for white wash.

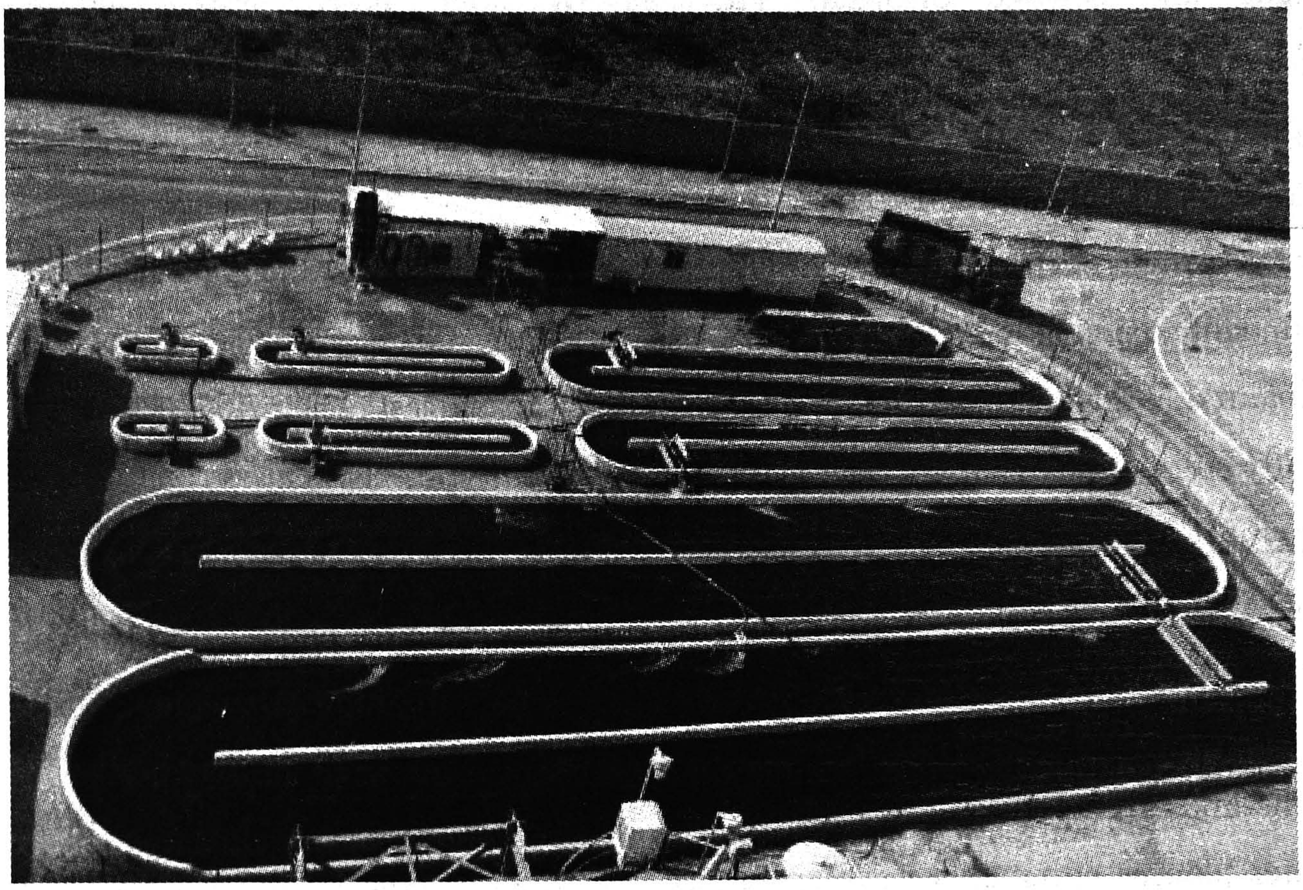
Wasteland reclamation: Another important use of the blue-green algae is in the reclamation of barren, alkaline, and saline usar soils. Such soils have been reclamined and brought to a productive state by the growth of Cyanophyceae. Algae such as *Nostoc, Scytonema* and *Anabaena* grow as thick stratum on surface of saline *Usar* soils during the rainy season. They have capacity to reclaim usar soils. Reclamation will follow a series of successful algal growth on such soils in a waterlogged condition. It has been possible to row rice after one year of

reclamation. The pH of alkaline soil in the presence of such algae is reduced from 10 to 7 and water holding capacity is increased by 40 %. Blue-green algae neutralize the alkalinity and increase fertility of the soil. In North India, (Banthara near Lucknow) *Nostoc commune* grow extensively up to several miles in saline *Usar* soils and adds the organic matter and increases the nitrogen content by 40 %.

Algae and space travel: Biologist can use microscopic, unicellular algae such as *Chlorella pyrenoidosa* as food source in space flight. It multiples rapidly and will synthesize a rich protein food utilizing CO_2 and liberating sufficient O_2 as a by-product for use.

Algae as food: Algae can play an important role in the production of protein for human food. The colonies of *Nostoc* are boiled and used as food in Brazil. In the pacific islands raw red, and brown algae are chopped and added to their dishes. *Ulva lactuca* was used in salad and soups in Scotland. *Porphyra* (laver) is considered a tasteful dish in England and is a common item of diet in Korea, Japan and China. It is rich in Vitamins B and C. *Caulerpa racemosa* is cultivated in Philippines as a source of food. In China and Japan some seaweeds are regularly harvested as food for man.

The algae are considered rich in proteins, fats and vitamins A,B,C and E. The vitamins A and D, which are commercially obtained from the livers of shark and similar fish, originally come from synthesis by the plankton algae.



Use of Algae as Fodder: The seaweeds are used as a fodder for animals. Norway, France, USA, Denmark and New Zealand are the countries where seaweeds are used as fodder for the cattle. The processed food is given to cattle, poultry and pigs. The egg laying capacity, thickness of the shell and yellow yolk content of the egg in the poultry increases. Butter and fat content of milk increased.

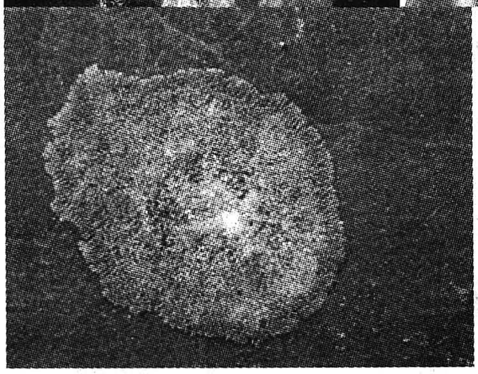
Role of Algae in Medicine: Agar-agar is an important algal product used in the manufacture of pills and ointments. Many types of seaweed contain a high % of Iodine content. They are used in the preparation of various thyroid medicines. A patient suffering from prolapsed stomach regains its normal condition after consuming agar powder with sufficient amount of water. Agar is also used as laxative. Chlorellin is an antibiotic extracted from Chlorella. Carrageenin extract acts as blood Coagulant. Alginic acid stops bleeding. Unani doctors use many algae in the treatment of lung, kidney and bladder ailments.

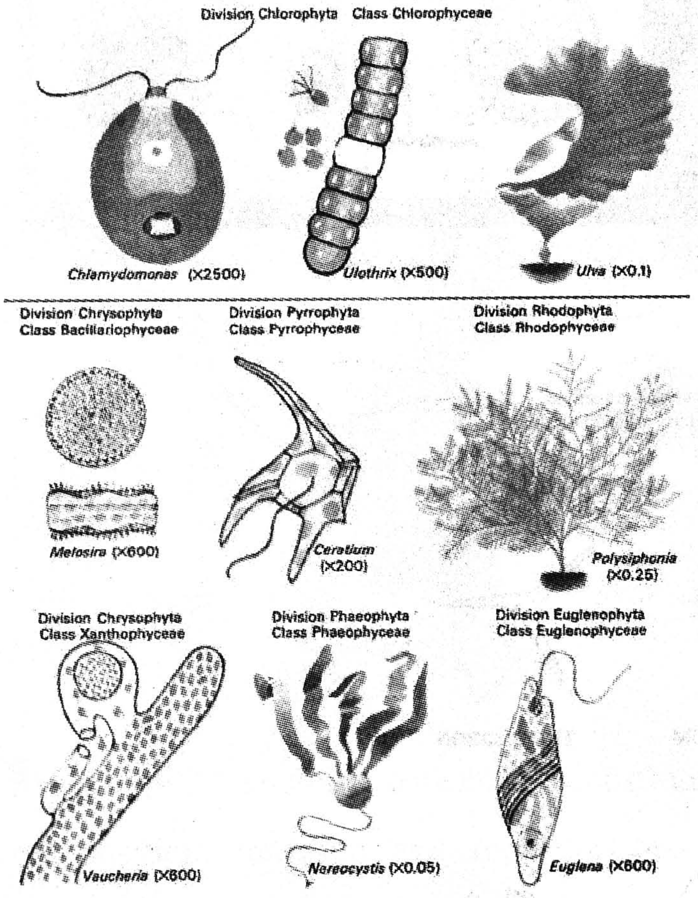
Algae as Pollution indicators: Some algal species are more tolerant and dominant in polluted water. Since these algae indicate the presence of pollutants in water, they are known as pollution indicators. Algae detect pollution rapidly. Generally green algae and diatoms are sensitive towards various pollutants, but blue-green algae are tolerant towards pollutants.

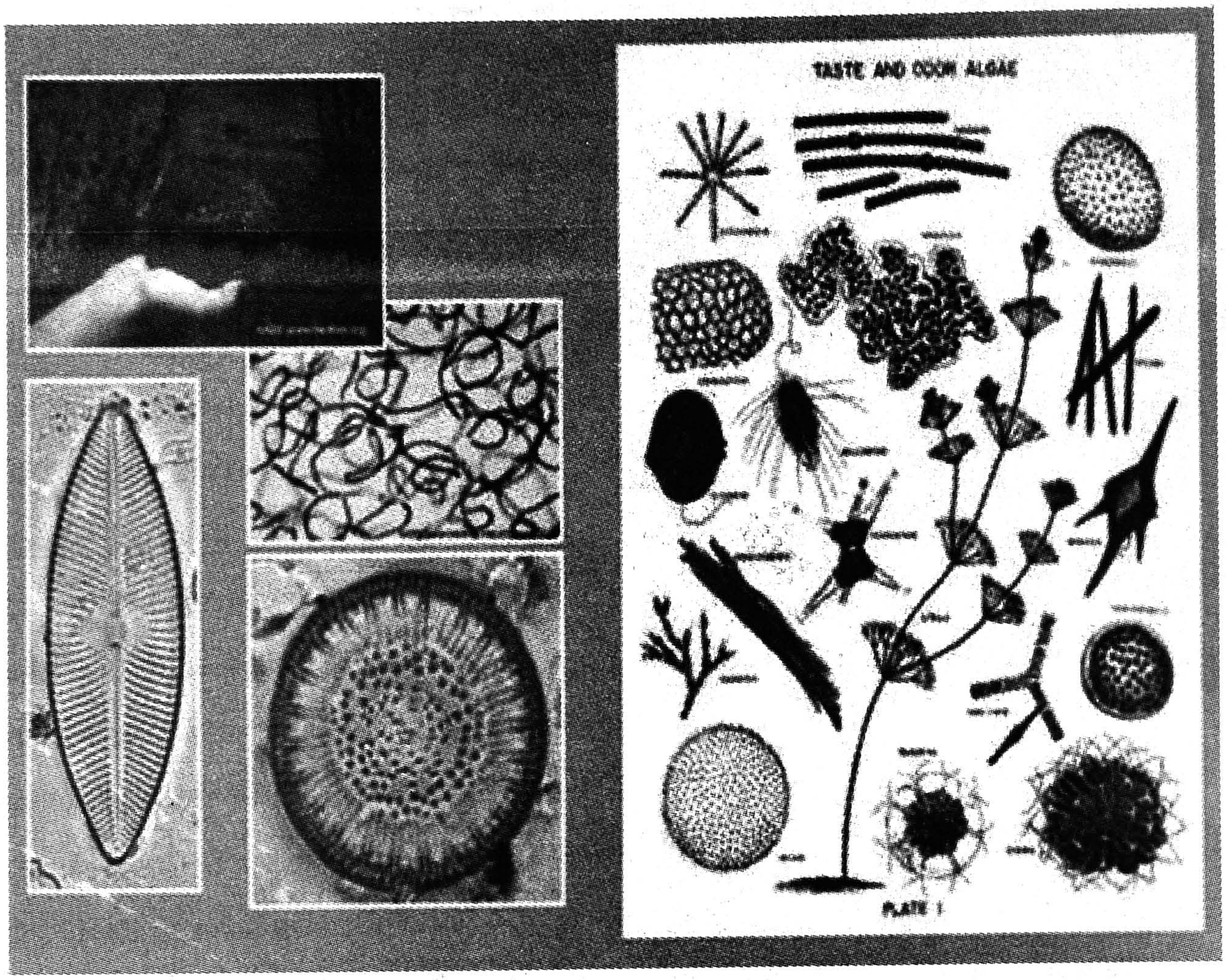
Algae and sewage disposal: The use of small green algae such as *Chlamydomonas, Chlorella* and *Euglena* in sewage oxidation ponds has proved a rapid, cheap and effective means of converting the dangerous waste into an odorless and valuable fertilizer. Mineral nutrients present in the sewage are used by the growth of the algae. The rapid photosynthetic activity of the algae produces abundant oxygen. Aerobic bacteria use these O_2 for decomposition of the remaining organic matter in the sewage. The treated effluent can be used for paddy cultivation or for coconut plantation or for culturing fishes.

Harmful Roles of Algae:

Algae and water supplies: The algae are of negative value as well. In the rainy season the blue-green algae, some green algae and the diatoms become so abundant in the ponds, lakes and reservoirs becomes yellowish or greenish tinge. Sometimes green scum may develop on the surface of water called water blooms. Water blooms commonly develop in city reservoirs, temple ponds, and lake and water tanks. It produces unpleasant odor, oily and fish taste to the drinking water. Water blooms increase the acidity of water. As a result the water becomes corrosive on metallic pipes and concretes. Some of the blue green algae, *Microcystis* produce toxins which is poisonous to fish, cattle, sheep and other domesticated animals. Some dinoflagellates like *Prymnesium* and *Gymnodinium* produce endotoxins, which cause paralysis, troubles in digestion and respiratory disorders. Some parasitic algae like *Cephaleuros* cause rust disease in tea and coffee plantation.

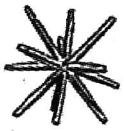



Division Chlorophyta Class Chlorophyceae
Chlamydomonas (X2500)
Ulothrix (X500)
Ulva (X0.1)
Division Chrysophyta Class Bacillariophyceae
Melosira (X600)
Division Pyrrophyta Class Pyrrophyceae
Ceratium (X200)
Division Rhodophyta Class Rhodophyceae
Polysiphonia (X0.25)
Division Chrysophyta Class Xanthophyceae
Vaucheria (X600)
Division Phaeophyta Class Phaeophyceae
Nereocystis (X0.05)
Division Euglenophyta Class Euglenophyceae
Euglena (X600)



GREEN ALGAE

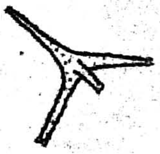
Grass-green in color. Great variety of forms: one-celled, simple or well-organized colonies, simple or branched filaments. Moving or motile forms have whip-like hairs or *flagella*.



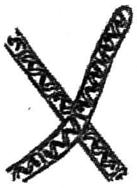
ACTINASTRUM

SCENEDESMUS

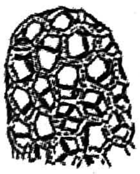
PEDIASTRUM



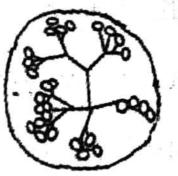
TETRAEDRON



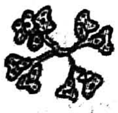
SPIROGYRA



HYDRODICTYON



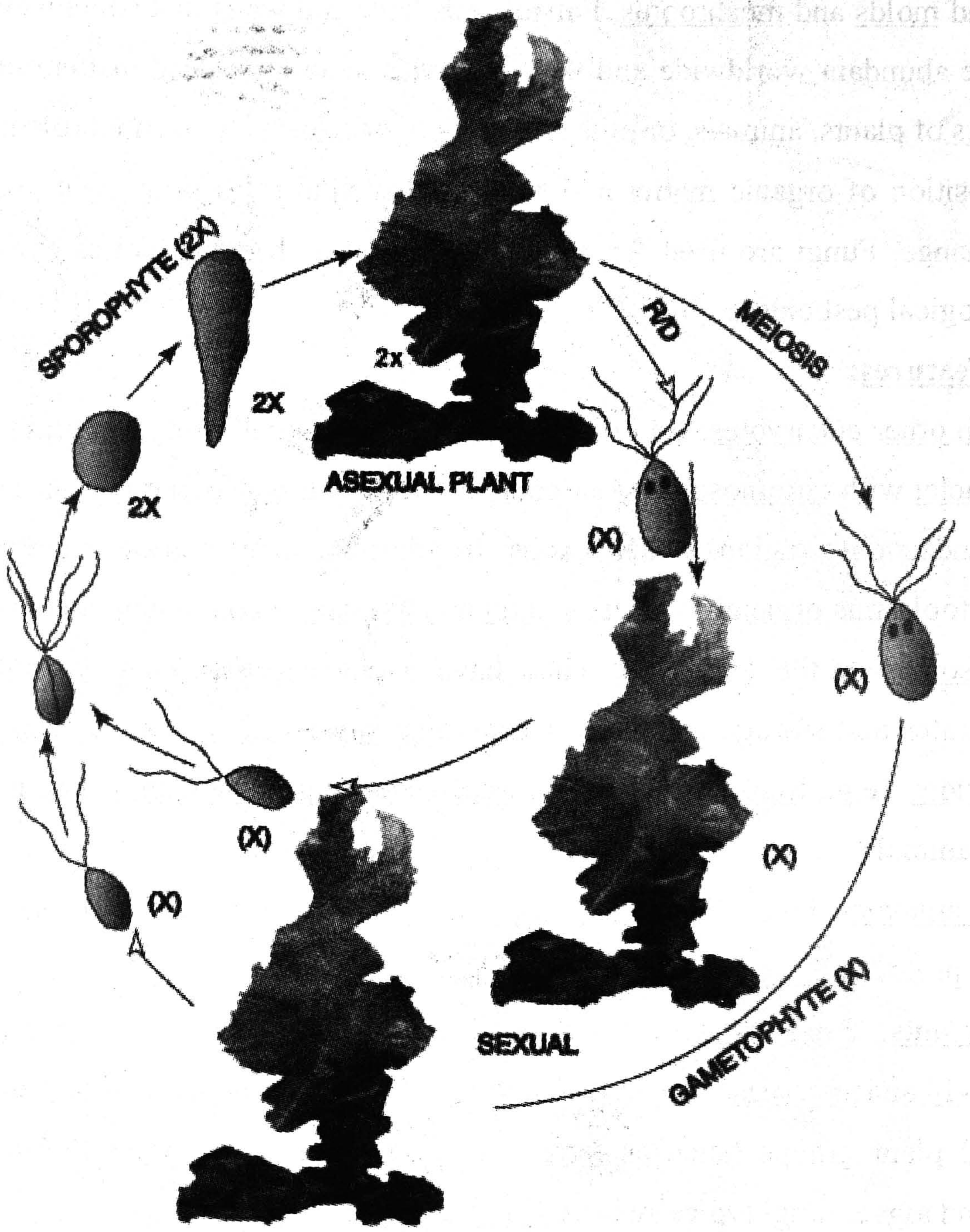
DICTYOSPHAERIUM



DIMORPHOCOCCUS

WOLFFIELLA

OOCYSTIS



Mycology: General characters; substrate relationship, structure, cell wall composition, nutrition and reproduction, heterothallism, parasexuality; recent trends in classificaton. Genral account; Mastigomycotina, Zycomycotina, Ascomycotina, basidiomycotina, Deuteromycotina. Outline of ecological significance and economical importance of fungai. Lichens – general account; economic importance.

General characters: The fungal kingdom has been estimated to contain about 1.5 million species; a recent (2011) estimate suggests there may be over 5 million species. A fungus is an eukaryotic organisms. It includes microorganisms such as

yeasts and molds and mushrooms. Fungal cells have cell walls that contain chitin. Fungi are abundant worldwide and their lifestyles in soil, on dead matter, and as symbionts of plants, animals, or other fungi. Fungi perform an essential role in the decomposition of organic matter and have fundamental roles in nutrient cycling and exchange. Fungi are used for making bread, wine, beer,antibiotics enzymes and biological pesticides.

Shared features:

With other eukaryotes: As other eukaryotes, fungal cells contain membrane-bound nuclei with chromosomes that contain DNA with noncoding regions called introns and coding regions called exons. In addition, fungi possess membrane-bound cytoplasmic organelles such as mitochondria, sterol-containing membranes, and ribosomes of the 80S type. They have a characteristic range of soluble carbohydrates and storage compounds, including sugar alcohols (e.g., mannitol), disaccharides, (e.g., trehalose), and polysaccharides (e.g., glycogen, which is also found in animals·

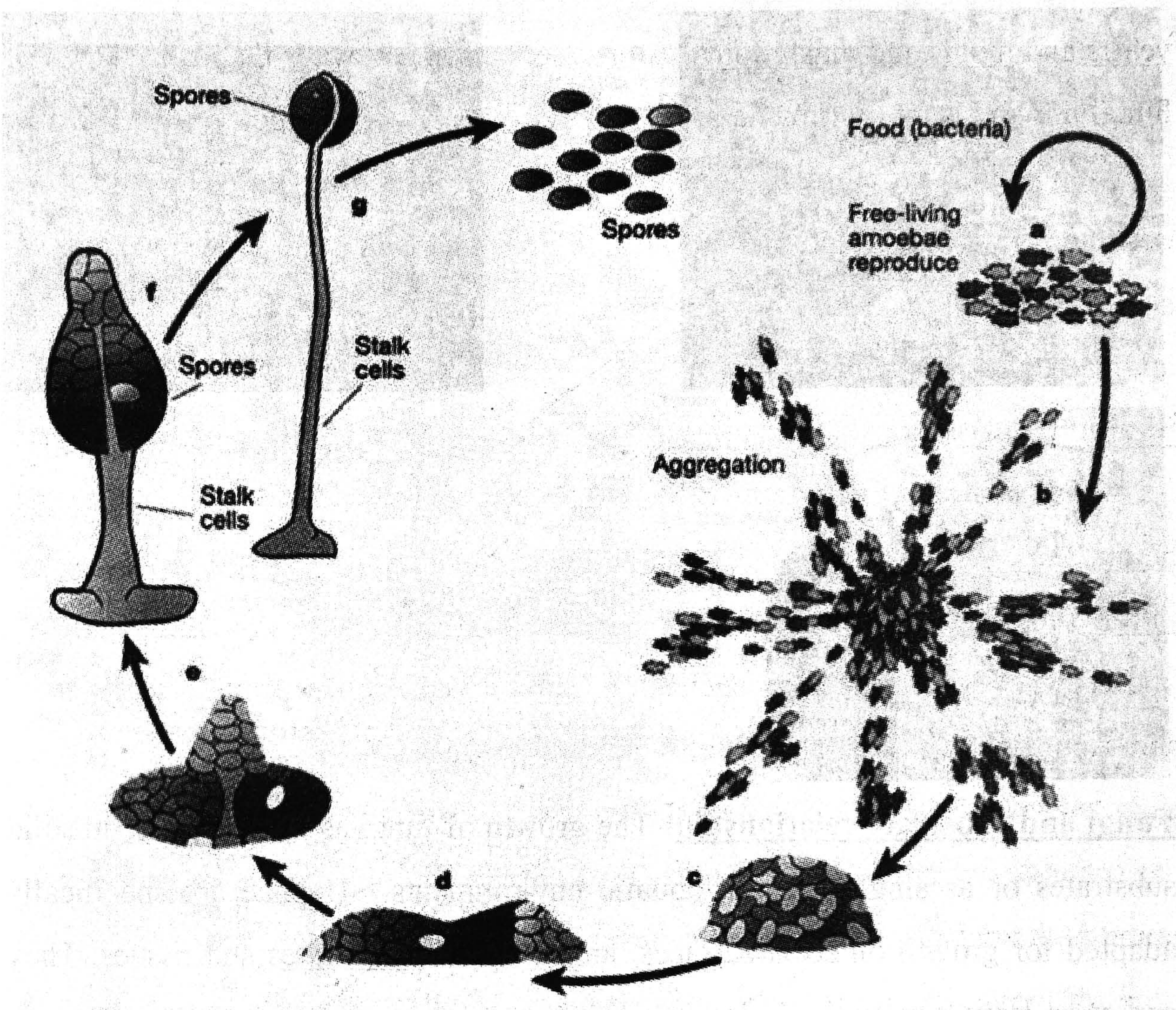
With animals: Fungi lack chloroplasts and are heterotrophic organisms, requiring preformed organic compounds as energy sources.

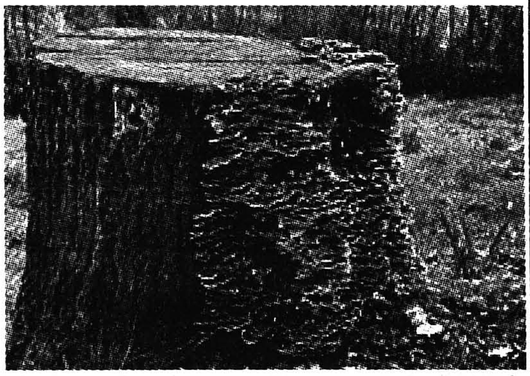
With plants: Fungi possess a cell wallhttp://en.wikipedia.org/wiki/Fungus - cite_note-14 and vacuoles. They reproduce by both sexual and asexual means, and like basal plant groups (such as ferns and mosses) produce spores. Similar to mosses and algae, fungi typically have haploid nuclei.

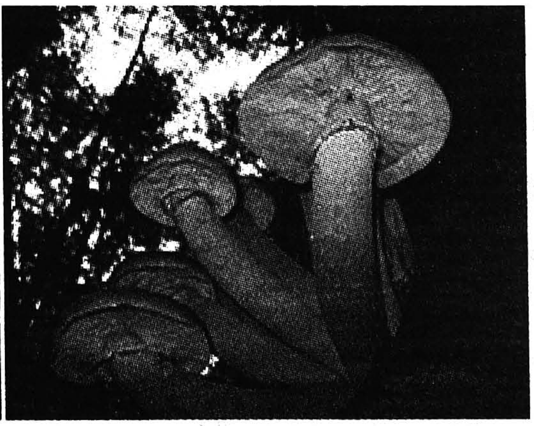
With euglenoids and bacteria: Higher fungi, euglenoids, and some bacteria produce the amino acid L-lysine in specific biosynthesis steps, called the α-aminoadipate pathway

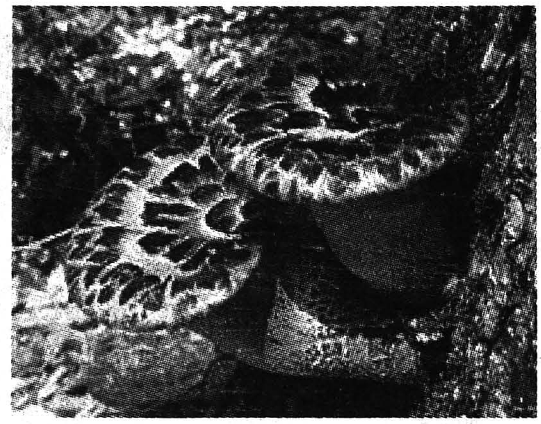
Unique features:

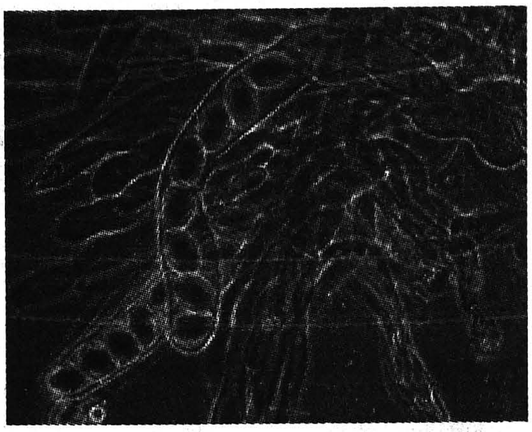
Some species grow as single-celled yeasts that reproduce by budding or binary fission. Dimorphic fungi can switch between a yeast phase and a hyphal phase in response to environmental conditions.

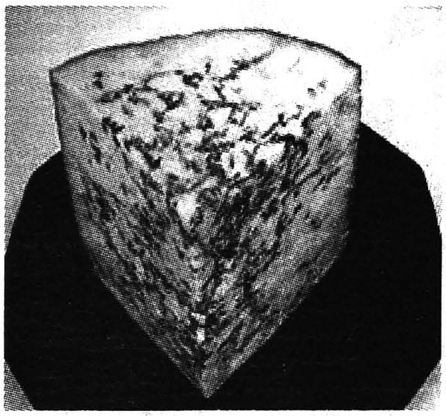

Spores
Spores
Food (bacteria)
Free-living
amoebae
reproduce
a
b
Aggregation
c
d
Spores
Stalk cells
Stalk cells
f
g





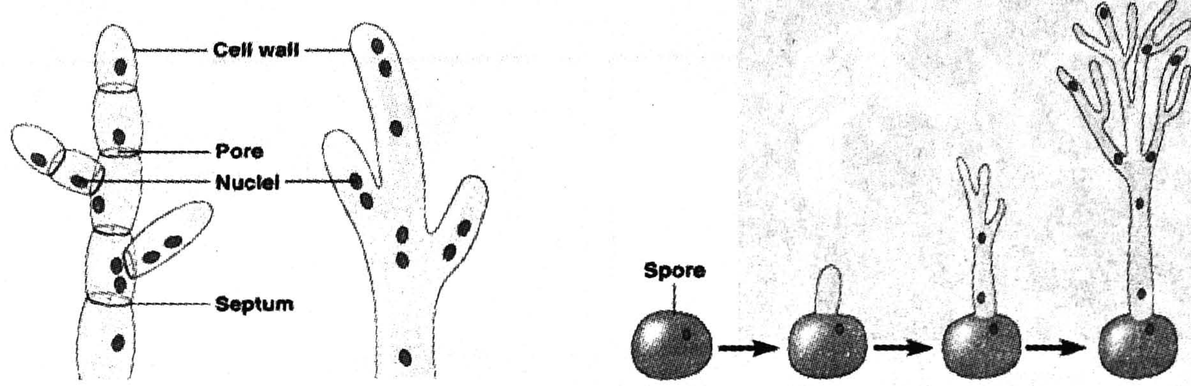






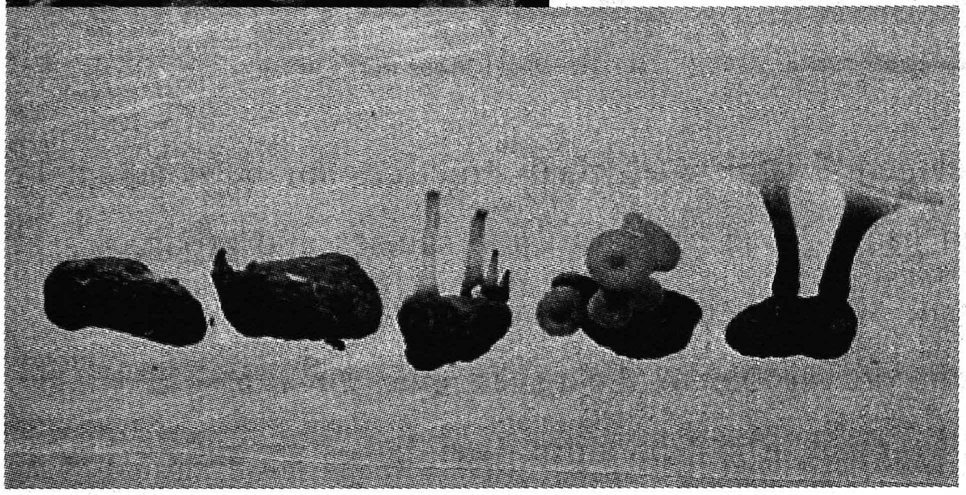
Fungi and substrate relationship: The growth of fungi as hyphae on or in solid substrates or as single cells in aquatic environments. Hyphae are specifically adapted for growth on solid surfaces, and to invade substrates and tissues. They can exert large penetrative mechanical forces; a structure called an appressorium that puncture plant tissues. The mechanical pressure exerted by the appressorium is generated from physiological processes that increase intracellular turgor by producing osmolytes such as glycerol. Structure: Most fungi grow as hyphae, which are cylindrical, thread-like structures 2–10 µm in diameter and up to several centimeters in length. Hyphae grow at their tips (apices); new hyphae are formed by emergence of new tips along existing hyphae by a process called *branching*, or occasionally growing hyphal tips bifurcate (fork) giving rise to two parallel-growing hyphae. The combination of apical growth and branching/forking leads to the development of a mycelium, an interconnected network of hyphae. Hyphae can be either septate or coenocytic: septate hyphae are divided into compartments separated by cross walls with each compartment containing one or more nuclei; coenocytic hyphae are not compartmentalized. Septa have pores that allow cytoplasm, organelles, and sometimes nuclei to pass through; an example is the

dolipore septum in the fungi of the phylum Basidiomycota. Coenocytic hyphae are multinucleate.



(a) Septate hypha (b) Coenocytic hypha (c) Growth of a hypha from a spore

Many species have developed specialized hyphal structures for nutrient uptake from living hosts calaled haustoria in plant-parasitic species and arbuscules of several mycorrhizal fungi, which penetrate into the host cells to consume nutrients. Fungal mycelia are visible to the naked eye. for example, molds. Mycelia grown on solid agar media in laboratory petri dishes are referred to as colonies. These colonies can exhibit growth shapes and colors (due to spores or pigmentation) that can be used as diagnostic features in the identification of species or groups. The apothecium is a specialized structure important in sexual reproduction in the ascomycetes—is a cup-shaped fruiting body that holds the hymenium, a layer of tissue containing the spore-bearing cells. The fruiting bodies of the basidiomycetes (basidiocarps) and some ascomycetes can sometimes grow very large, and many are well known as mushrooms.

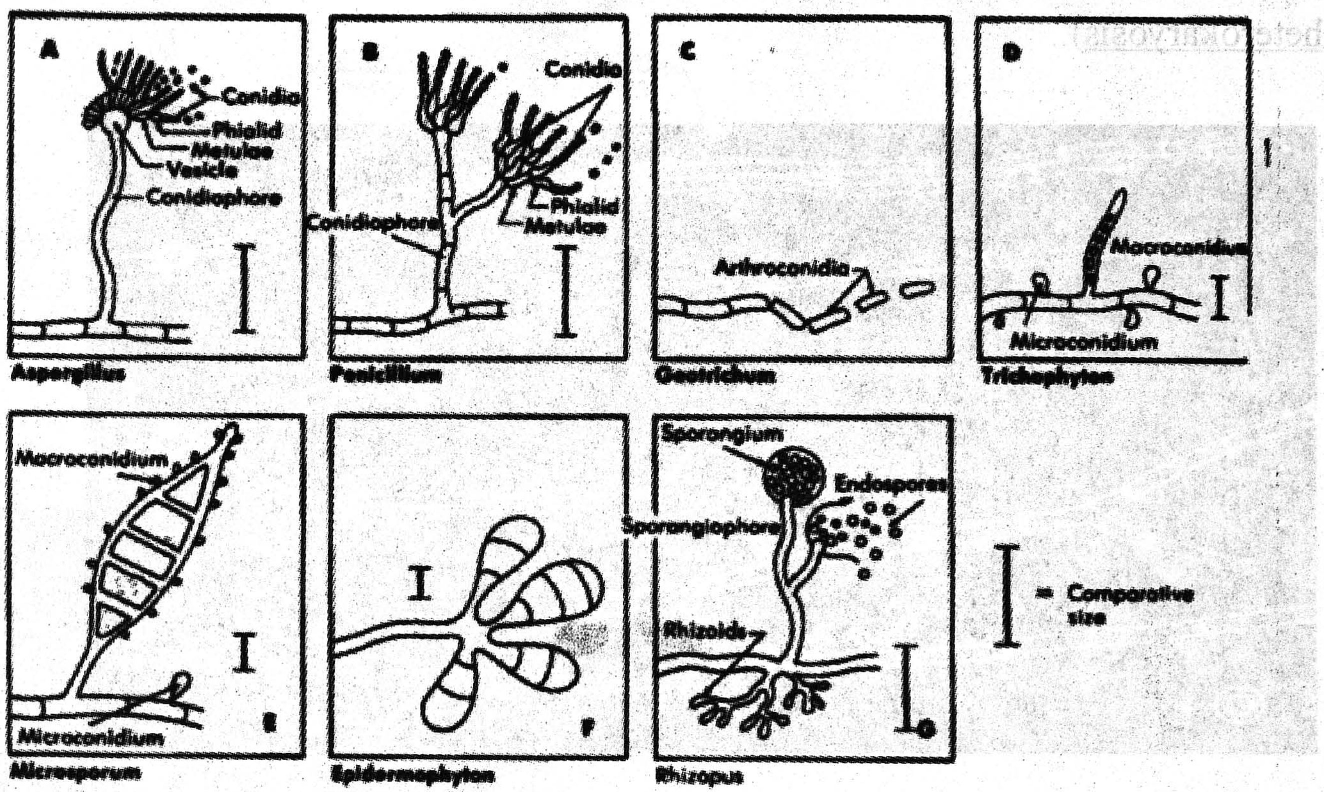


Cell wall composition: The fungal cell wall is composed of glucans and chitin; The glucans are also found in plants and the Chitin is present in the exoskeleton of arthropods, fungi are the only organisms that combine these two structural molecules in their cell wall. In contrast to plants and the oomycetes, fungal cell walls do not contain cellulose. Nutrition: The fungi are heterotrophs, organisms that rely solely on carbon fixed by other organisms for metabolism. The majority of filamentous fungi grow in a polar fashion—i.e., by extension into one direction—by elongation at the tip (apex) of the hypha. Fungi use a diverse range of organic substrates for growth, including simple compounds such as nitrate, ammonia, acetate, or ethanol. Some species has the pigment melanin play a role in extracting energy from ionizing radiation, such as gamma radiation; however, this form of "radiotrophic" growth has been described for only a few species.

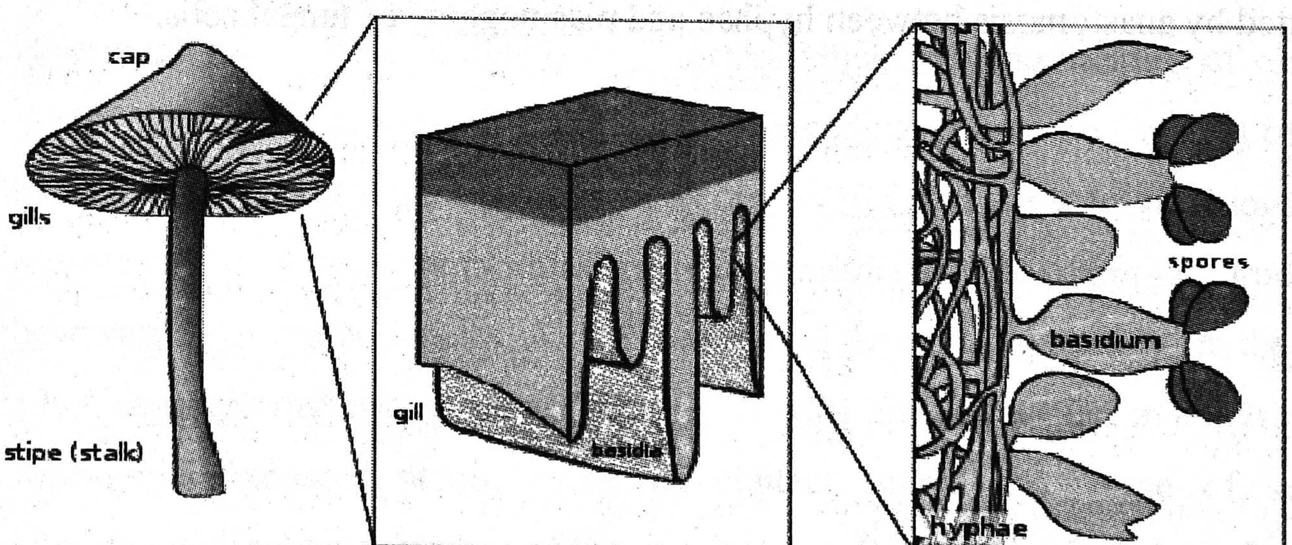
Reproduction: Fungal reproduction is complex, reflecting the differences in lifestyles and genetic makeup within this diverse kingdom of organisms.

Asexual reproduction via vegetative spores (conidia) or through mycelial fragmentation is common; The "Fungi imperfecti" (fungi lacking the perfect or

sexual stage) or Deuteromycota comprise all the species which lack an observable sexual cycle.

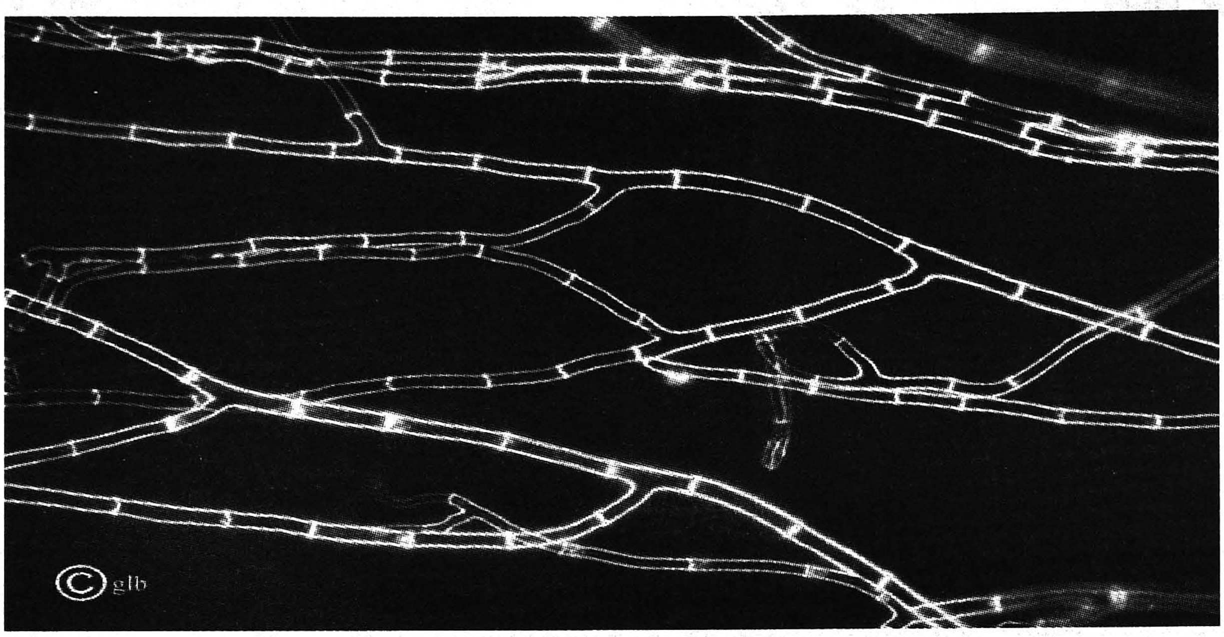


Sexual reproduction with meiosis exists in many fungai. The spore-containing structures, asci and basidia, are used in the identification of ascomycetes and basidiomycetes, respectively. Some species may allow mating only between individuals of opposite mating type, while others can mate and sexually reproduce with any other individual or itself. Species of the former mating system are called heterothallic, and of the latter homothallic.



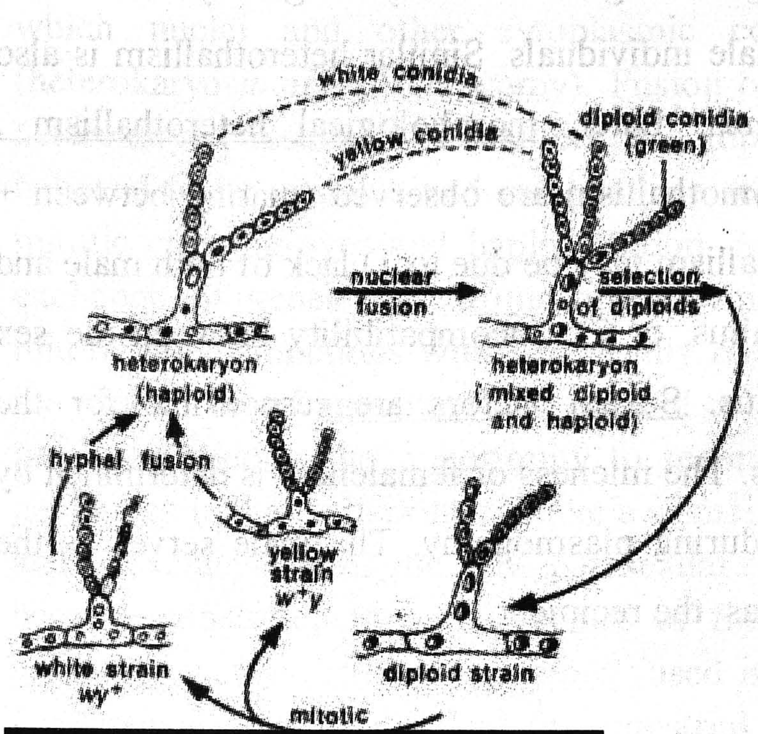
Most fungi have both an haploid and diploid stage in their life cycles. In sexually reproducing fungi, compatible individuals may combine by fusing their hyphae together into an interconnected network; this process, anastomosis, is required for

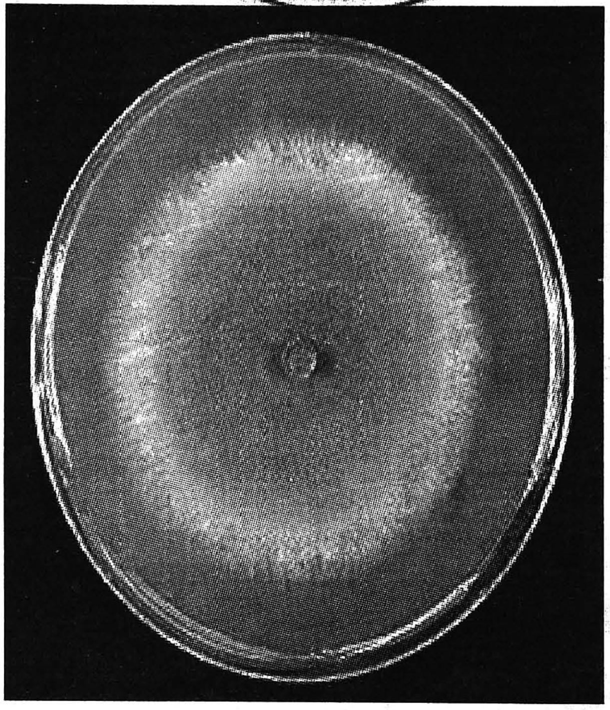
the initiation of the sexual cycle. Ascomycetes and basidiomycetes go through a dikaryotic stage, in which the nuclei inherited from the two parents do not combine immediately after cell fusion, but remain separate in the hyphal cells (see heterokaryosis).



Both asexual and sexual spores and sporangiospores are actively dispersed by forcible ejection from their reproductive structures. This ejection ensures exit of the spores from the reproductive structures as well as traveling through the air over long distances.

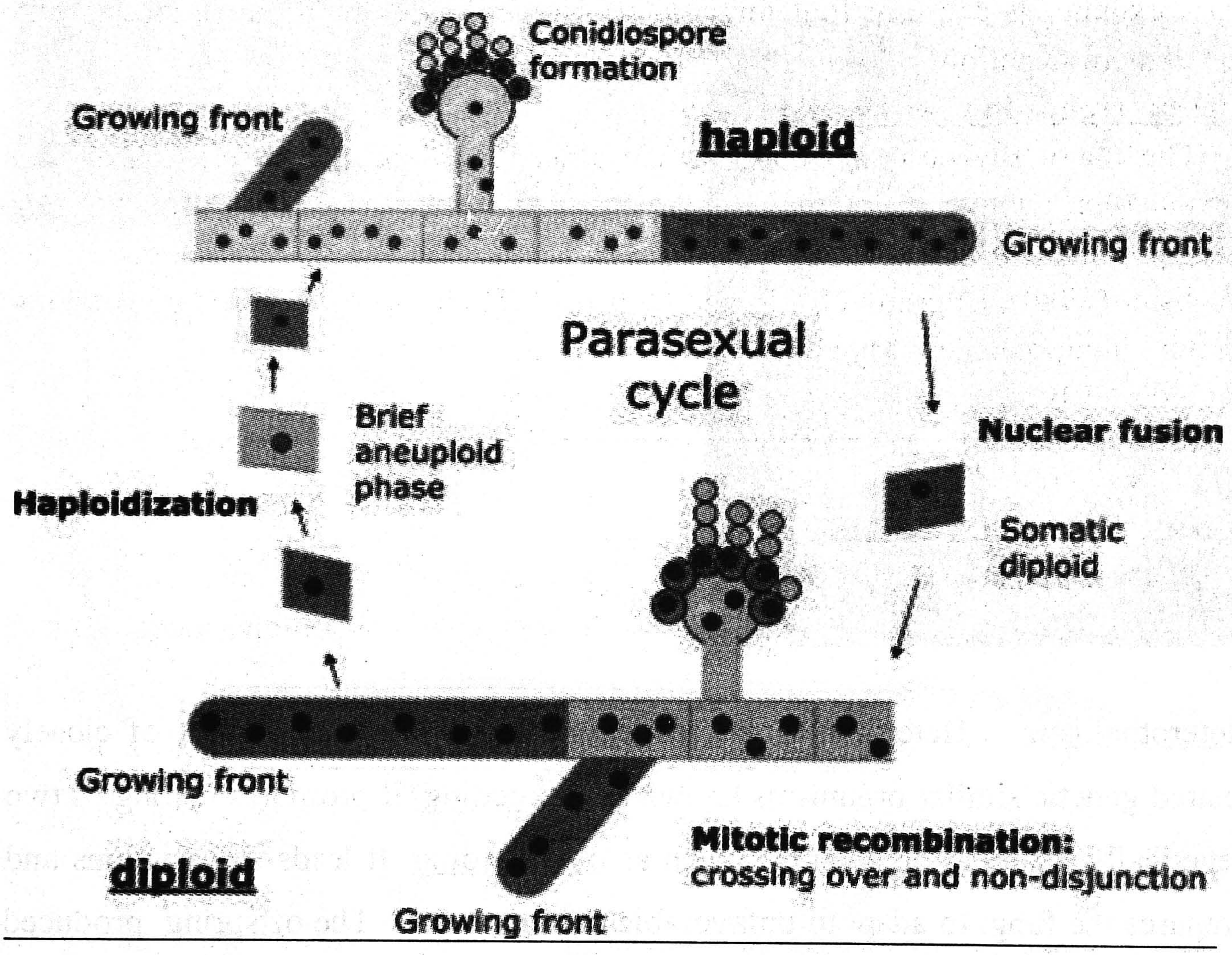
Besides regular sexual reproduction with meiosis, certain fungi, such as *Penicillium* and *Aspergillus*, exchange genetic material via parasexual processes, initiated by anastomosis between hyphae and plasmogamy of fungal cells.





Heterothallism: Heterothallism is a device which prevents mating of closely related genetic similar organisms known as Inbreeding. It promotes mating of two genetically different organisms known as out breeding. It leads to variations and prepares the fungi to adapt to unfavorable circumstances. The offspring produced have variety of characteristics. A.F. Blakeslee, an American geneticist, in the year 1904, observed that two species of *Mucor hiemalis* grown together in a Petri dish, zygospores appeared at the point of contact (conjugation type of sexual reproduction) between hyphae of the two isolates. Blakeslee called these fungi as heterothallic and the phenomenon as heterothallism. He designated the mating

types, as (+) and (-) strains. Their gametangia were morphologically similar and indistingusihable into male and female individuals. Similar heterothallism is also observed in the *Rhizopus nigricans*. Later, morphological heterothallism , physiological heterothallism and homothallism are observed (mating between + and + or – and – strains). Heterothallism may be due to 1) lack of both male and female sex organs on the same thallus, or 2) incompatibility between the sex organs formed on the same thallus. Sexual factors are responsible for the formation of sex organs and gametes. The mleness or femaleness is determined by the direction of nuclear migration during plasmogamy. The male serves as the donor of the nucleus and the female as the recipient.



Parasexuality: The parasexual cycle (or parasexuality), a process peculiar to fungi, is a nonsexual mechanism for transferring genetic material without meiosis or the development of sexual structures. It was first described by Italian geneticist Guido Pontecorvo in 1956 during studies on *Aspergillus nidulans*

A parasexual cycle is initiated by the fusion of hyphae (anastomosis) during which nuclei and other cytoplasmic components occupy the same cell (heterokaryosis and plasmogamy). Fusion of the unlike nuclei in the cell of the heterokaryon results in formation of a diploid nucleus (karyogamy), which is believed to be unstable and can produce segregants by recombination involving mitotic crossing-over and haploidization. Mitotic crossing-over can lead to the exchange of genes on chromosomes; while haploidization probably involves mitotic nondisjunctions which randomly reassort the chromosomes and result in the production of aneuploid and haploid cells. Like a sexual cycle, parasexuality gives the species the opportunity to recombine the genome and produce new genotypes in their offspring. Unlike a sexual cycle, the process lacks coordination and is exclusively mitotic. The parasexual cycle under laboratory conditions has been demonstrated in many species of filamentous fungi, including *Fusarium monoliforme*, *Penicillium roqueforti* (used in making blue cheeses. Significance: Parasexuality is a useful tool for industrial mycologists to produce strains with desired combinations of properties.

Recent trends in Classification:

The major divisions of fungi are classified based on characteristics of their sexual reproductive structures. A more natural system of classificaton of fungi was proposed by Ainsworth (1973) and accepted by many Mycologists like Webster (1980), Bilgrami (1985) and Dube (1987). Ainsworth placed all the fungi in the kingdom called Mycota.

Kingdom Mycota

Division: Myxomycota (4 classes)

Division Eumycota

Sub-divisions:

1. Mastigomycotina(3)
2. Zygomycotina(2)
3. Ascomycotina(6)
4. Basidiomycotina(3)
5. Deuteromycotina(3)

General account of Myxomycota: (slime molds)

1. The thallus is a non-green, multinucleate mass of protoplasm called the plasmodium.
2. The plasmodium lacks a definite cell wall and shows amoeboid in shape.
3. It is free living, diploid and holocarpic
4. The spores are differentiated by Meiosis.

General account of Mastigomycotina:

1. Absorptive nutrition, unicellular or filamentious, mycelium coenocytic.
2. Three classes: Chytridiomycetes, Hyphochytridiomycetes and Oomycetes.
3. Zoospores of Chytridiomycetes has single whiplash flagellum inserted at the posterior end.The members of this class are called chytrids.
4. Motile cells of Hyphochytridiomycetes has single tinsel flagellum inserted at the anterior end.
5. Plasmodiopphoromytcetes are parasitic fungi producing biflagellate motile cells with both the flagella of whiplash type inserted at the anterior end.One is longer and other is shorter. Ex. Club root organisms.

General account of Zygomycotina:

Two classes, Zygomycetes and Trichomycetes.

1. Motile cells are absent in the Zygomycetes. Asexual reproduction takes place by sporangiophores . It is encapsulated and wind disseminated. Ex. Bread molds.
2. Motile cells are absent. The asexual spores are produced exogenously at the tips of special hyphae (conidiophores) and are called Conidia.

General account of Ascomycotina:

Six classes: Henuascomycetes, Loculoascomycetes, Plectomycetes, Laboulbeniomycetes, Pyrenomycetes and Discomycetes.

1. Well-developed somatic phase, brnached mycelium with regular septation of the hyphae. The cross walls have minute, central, simple pore.
2. Meiospores of the perfect stage are known as the Ascospores are endogenous in origin.

3. The ascospores are produced in small, thin-walled sac-like, sproe-producing units called the Asci (sing. Ascus) present in the special type of explosive sporangium called Ascocarp. It is a product of sexual reproduction.
4. Dikaryophase in the life cycle is another important feature.
.5. Asexul reproduction takes place by means of non-motile, exogenously produced spores called conidia. They are produced terminally on speical, reproductive hyphae called the conidiophores.
6. Motile cells are completely absent in the life cycle.

General account of Basidiomycotina:

Three classes: Teliomycetes, Hymenomycetes and Gasteromycetes.

1. well developed somatic pahse, septate, filametous mycelium two stages; Primary mycelium , formed by the germination of a basidiospores (x), short lived. and Secondary or dikaryotic mycelium, food absorbing pahse (x+x) nuclei, long-lived, .
2. Motile cells ar eabsent in the life cycle.
3. 3.The clamp connections on the dikaryotic hyphae.
4. Homobasidiomycetidae do not form any asexual spores. The Heterobasidiomycetidae form dikaryotic mycelium. And produce uredospores and aeciospores in the rusts.
5. Sex organs are absent. Basidium is the characteristic reproductive organ. Sexual process is by plasmogamy and karyogamy.
6. Basidium bears four basidiospres exogenously.

General account of Deuteromycotina:

Three classes: Blastomycetes, Coelomycetes and Hyphomycetes.

Asexual or imperfect stage. Sexual stage or perfect stage is unknown. Haploid mycelium, septate and produsely brnached. Reproduction by the formation of exogeneously developed asexual spores (conidia, oidia or chlamydospores)

1. Blastomycetes: Budding cells with or without pseudomycelium; true mycelium lacking or not well developed

2. Coelomycetes: Spores produced in pycnidia or acervuli

3. Hyphomycetes: Mycelium sterile or bearing spores directly or on special branches (sporophores) variously aggregated

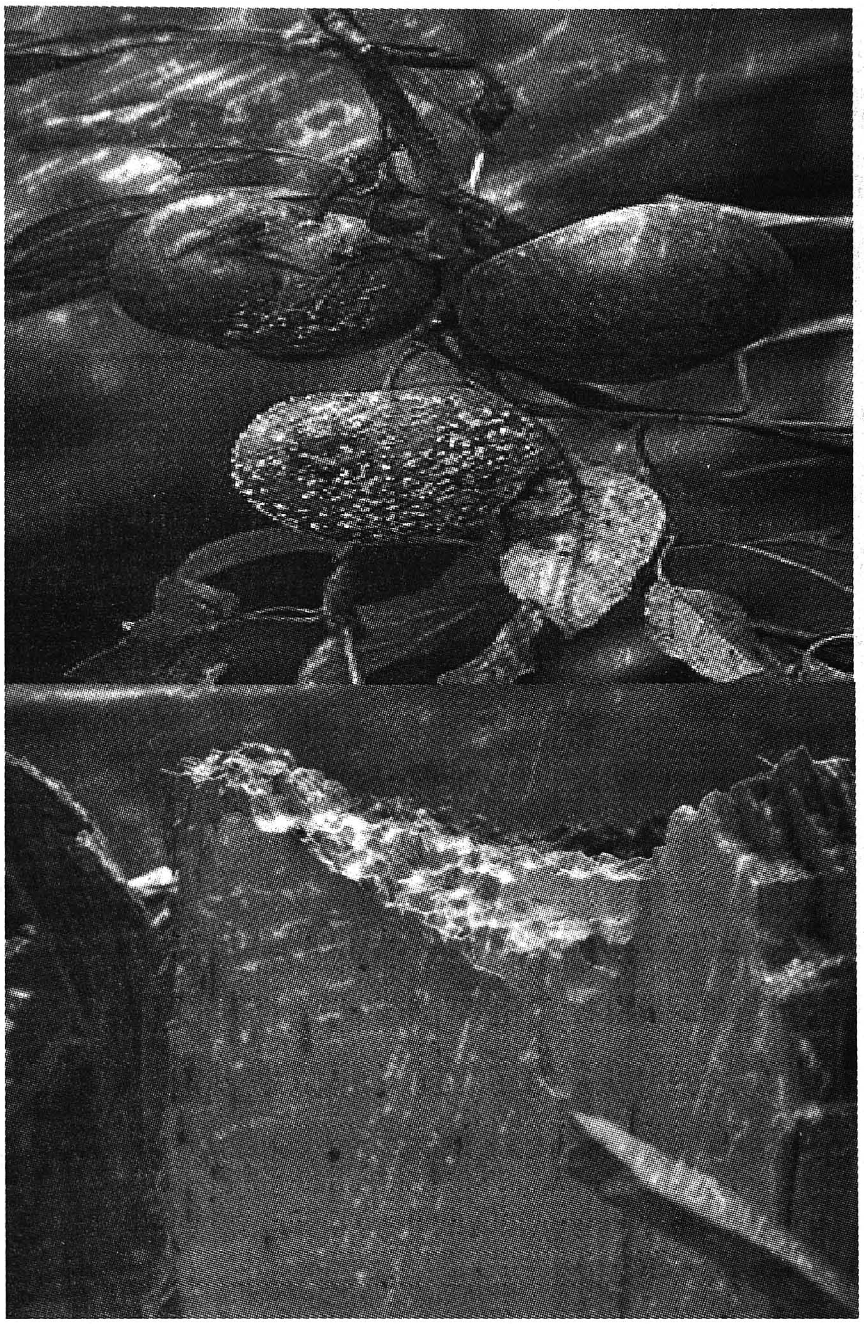
Ecological significance of fungi:

Fungi play a critical role in every ecosystem. They are key in recycling dead vegetation and making the nutrients available for the next generation of plant life. They form symbioses with many plants, colonize and convert unavailable nutrients inti available nutrients to plants. The following are the primary roles that fungi play in the world's ecosystems:

Saprotrophs:['dead eater'] Saprotrophs are fungi that assimilate dead plant tissues and decompose them. Many, many fungi fall into this category, especially the molds. Saprotrophs play a key role in recycling nutrients in most ecosystems, and are many times more effective than alternative organisms such as bacteria.

Most fungi are capable of digesting the large quantities of Cellulose contained in plant tissue. Some fungi are also capable of digesting lignin contained in woody plants and trees. Without these wood rotting fungi, fallen trees would take forever to fully decompose. Wood rotters are classified as **brown rot** and **white rot** fungi. These labels are regarding the appearance of the wood after the fungus has acted on it, and are used to aid identification.

Brown rot: Brown rot is caused by a wood rotter using enzymes that digest cellulose but leave the brown lignin. Wood that has been attacked by a brown rot fungus looks as cubes. This is called brown cubic rot, and is the result of major connective tissues being selectively digested.

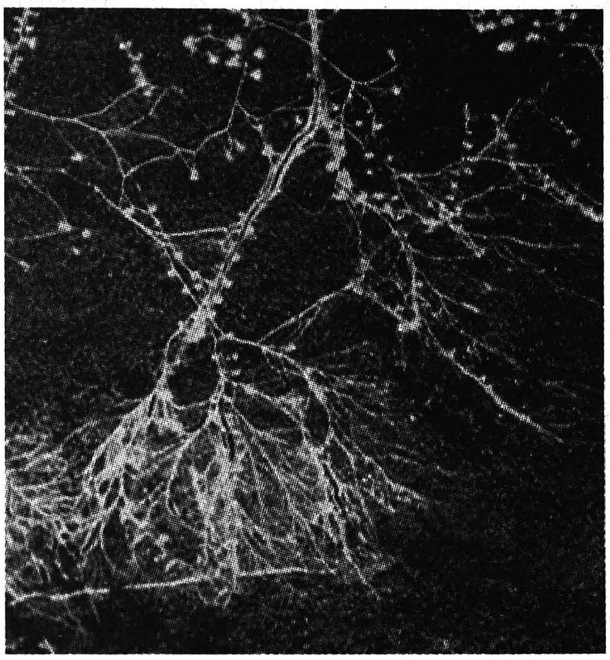


White rot: In contrast to brown rot, white rot is the result of lignin being digested, with some or all of the cellulose remaining behind. The use for white-rot fungi is as an alternative to using chemicals to prepare wood for paper manufacture. Wood is just one of many sources of nutrients for saprotrophs. Fungi that can't digest or can't compete with wood rotters find their niche in the leaf litter and forest humus. There are saprobic fungi species for every possible niche in an ecosystem's decomposition cycle. An important aspect of saprotrophic activity is that different fungi act on dead vegetation in different stages of decomposition. A pine needle can take up to 10 years to decompose into soil in a healthy conifer forest, and hundreds of different saprotrophs specialize in digesting the compounds that become available in that needle throughout the process. As in many other food webs, there are primary and secondary consumers. On the far end of the

saprotroph spectrum, **coprophageous** fungi are adapted to act on the dung of herbivores, especially ruminants, which contains plenty of partially digested vegetation. Many fungi are adapted to include ruminant dung in their lifecycle, including the commercial white button mushroom.

Mycorrhiza: Mycorrhiza are fungi adapted to live in Symbiosis with the roots of plants. All land plants on earth have mycorrhizal relationships. These relationships range from merely helpful to absolutely essential to the plant's survival. The fungus is called the **mycombiont**, and the plant is called the **photobiont**. The primary role of all mycorrhiza involves the uptake of phosphorous from the soil. Many plants have difficulty processing the form that phosphorous takes in the soil, but mycorrhizas have an easy time at it. There are plenty of other advantages, such as increased surface area and defense against root pathogens.

Glomerales: Mycobionts produce microscopic fruiting bodies underground. The glomerales are integrated with their photobionts: they penetrate the root cells and form interfaces called arbuscles . These fungi are also called endomycorrhiza, because part of them exist within the root cells. Although many plants do not require these mycombionts to survive, they provide a major advantage, especially in poor soils.



Ectomycorrhiza: Most of the ectomycorrhiza are macrofungi. It forms relationships with trees. They form fungal sheaths around root hairs, called **hartig nets**. Many trees absolutely require mycombionts to survive. All pines, oaks, alders, willows, poplars, and most eucalyptus have mycombionts, and many other tree species as well.

Economic importance of Fungi

A. Harmful economic aspects of fungi, i.e. negative aspects of fungi :

Spoilage of food, stored grains and other essential commodities--

Fungi (mould fungi) are the chief agents responsible for most of the disintegration of fruits, vegetables and other done stuffs, e.g. jams, jelly, pickles, bread, various cooked-foods eat. if not properly stored. Common food damaging fungi are *Aspergillus*, *Penicillium*, *Mucor* and *Rhizopus*.

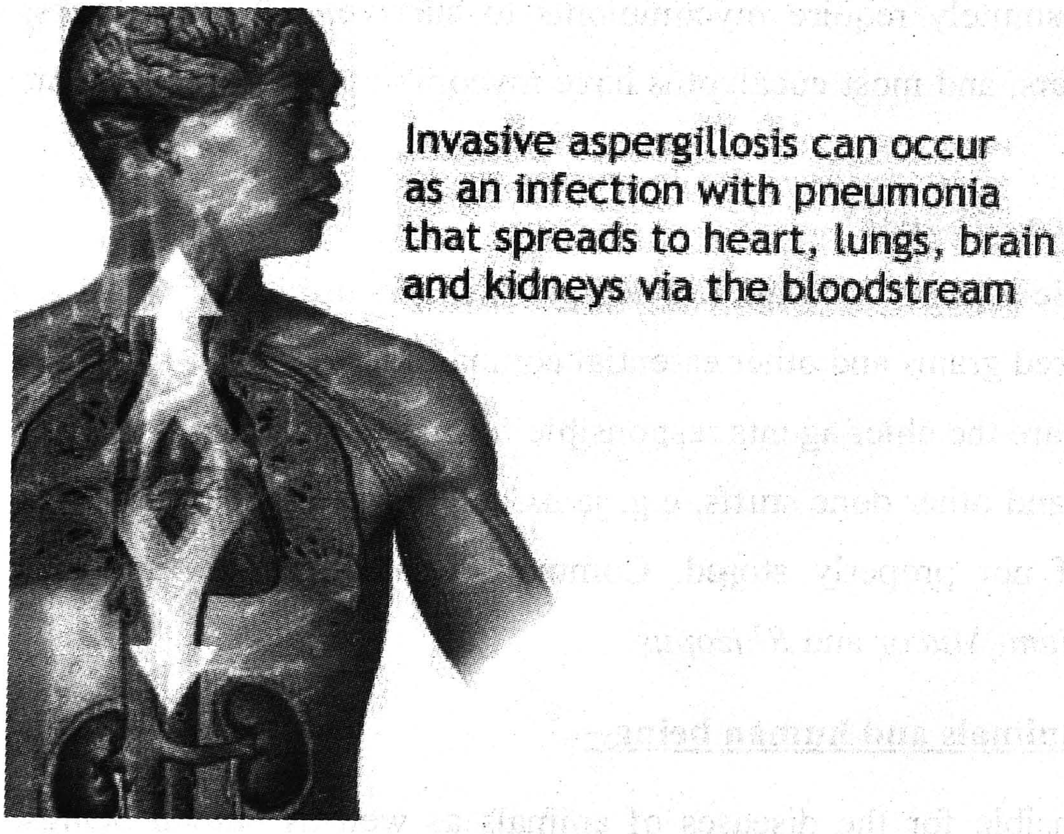
Induce diseases of animals and human being--

Fungi are responsible for the diseases of animals as well as human beings. Some of the serious diseases of human being, i.e. the diseases of skin, throat, nose and as well as bronchial and intestinal disorders are caused by various groups of fungi. A few species of *Mucor* and *Rhizopus* are common fungi infecting lungs,

brain and gastric system, *Neurospora* and *Fusarium* infect corneal tissue of eye.

Some Deuteromycetous and Ascomycetous fungi contaminate the stored harvested grains- the infected grains of wheat, maize etc. Stored grains contain spores and fungal hyphae beneath the outer layers. When such contaminated seeds and grains are consumed by animals and human being, they cause serious diseases including liver cancer. Besides infecting foods and grains, *Aspergillus*, *Penicillium* are also responsible for the destruction of fabrics, leather, paper, optical and electrical and other consumer's goods that are subject to fungal attack.

Several species of *Aspergillus* are human pathogens, causing a group of diseases collectively called Aspergilloses. *Aspergillus* infects nasal tissues and lungs. Candida albicans is the cause of many diseases in man. Skin candidiasis, broncho candidiasis, oral candidiasis, vulvo-vaginal candidiasis, palm, ovary candidiasis etc. are the examples of different types of candidiasis of human. Species of *Cercospora*, *Cryptococcus* and others infest animal and human bodies causing a disease known as mycosis.



Trichophyton and *Microsporum* are causing the diseases (aspergillosis), candidiasis, phycomycosis, and mycotic abortions in large number of animals in India. Ring worm of dogs and horses is caused by Microsporum canis. *Aspergillus fumigatus* cause cattle bovine abortion in many chickens, ducks and other birds. Mycotic abortions of cattle is very common disease.

Induce diseases of plants--

Fungi are also responsible for millions of rupees worth of damage to crops by causing plast diseases. Of the serious diseases of crop plants, 'damping off' diseases of potato plant caused by *Phythium debaryanum*; 'late blight' or 'rot' diseases of potato plant caused by *Phytophthora infestans*; 'downy mildew' diseases of crucifers caused by *Peronospora parasitica* etc. may be mentioned. The various members of polypores among Basidiomycotina are responsible in *Claviceps purpurea* (Ascomycotina) causes the 'ergot' disease of causing serious diseases and damages of timber and timber yielding plants, railway sleepers, wooden pillars, furniture etc. The members of 'rust' (*Puccinia*) and 'smut' (*Ustilago*, *Tilletia*, etc.) are also highly destructive to various different crop plants like wheat, maize, oat, barley etc. Many fungi cause immense lord to timber and lumber wei trees by causing wood-rot disease. rye.

Toxic substances obtained from fungi--

Several toxins are extracted from mushroom like *Amantia* phalloides. There toxins fall mainly in two groups such as phallotoxins and amatoxins. The extensively studied phallotoxin is **phalloidin** and amatoxin is **alfa-amanitin**. Both the toxins affect livers, stomach and intestine cells in the later stage.

Sclerotia of *Claviceps purpurea* contain many poisonous alkaloids such as ergotamine, ergometrine, ergo-crystinine, ergocristina and ergonovin. Symptoms of ergot poisoning in man are diarrhoea, abdominal pain, vomiting etc. The animals that feed on such *Sclerotia* may even abort; their legs, tail etc. may become gangrenous. *Aspergillus flavous* and *Aspergillus niger* infest dried foods and ground out meal and produce a dangerous toxins called **aflatoxin**-- this toxin has carginogenic effect.

- **Wood-rotting fungi--**

Many wood rotting fungi e.g. a few species of *Lentinus*, *Serpula lacrymans*, *Coniophora_cerebella*, etc. cause a great monetary loss. Dry rot and wet rot are most dangerous diseases of the timber.

i. Fungi growing in Aircraft fuel tanks--

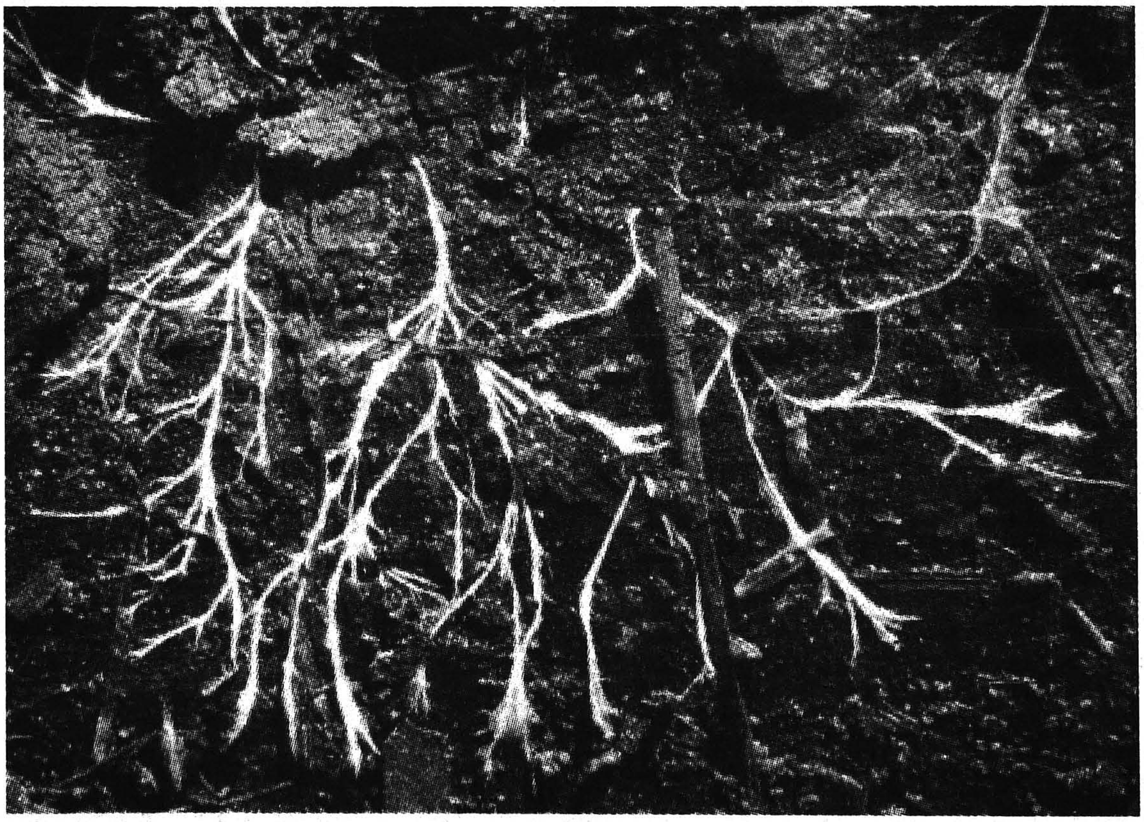
Amorphotheca resinae grow in the kerosene-based fuel tanks of aircrafts. This fungus grows in storage and fuel tanks profusely as a result fungal hyphae may plug the valves and pipes of the aircraft and cause disastrous effect during flight.

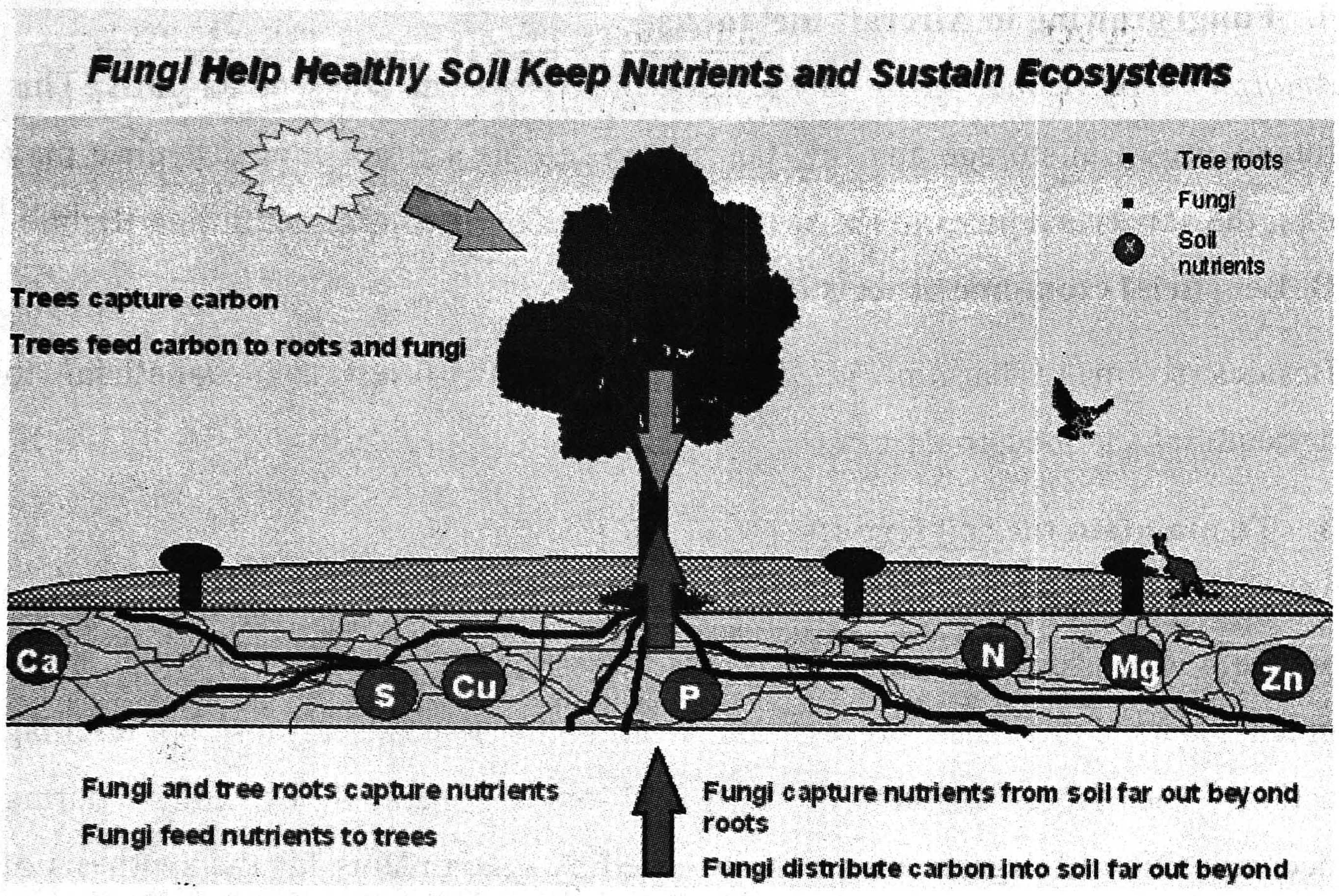
B. Beneficial economic aspects of fungi :

Besides so many harmful i.e. destructive effects, **fungi** also **beneficial** to agricultural and industrial fields.

i. To maintain the soil fertility--

Many saprophytic fungi along with bacteria decompose the dead organic matters and help in returning the nutrients (derived from the organic matters) to the soil to green plants. Fungi also prevent many inorganic substances lost by leaching action. The large amount of Carbon-di-oxide liberated by fungi during decomposition of organic matter is also used by green plants for the synthesis of their food.



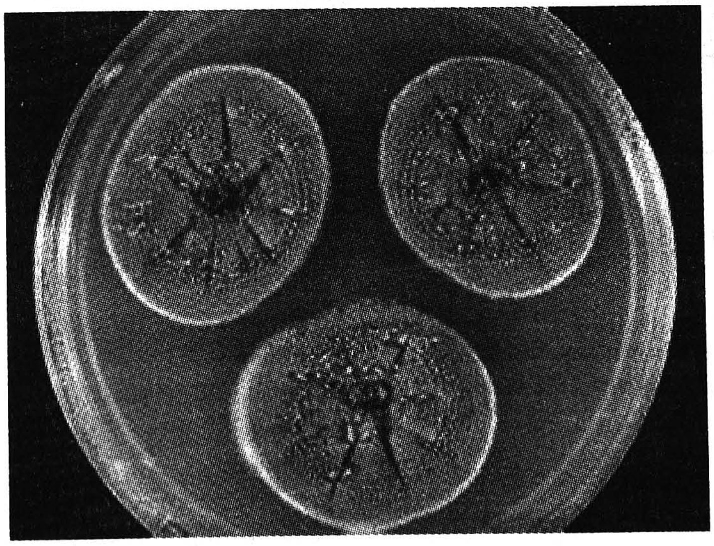


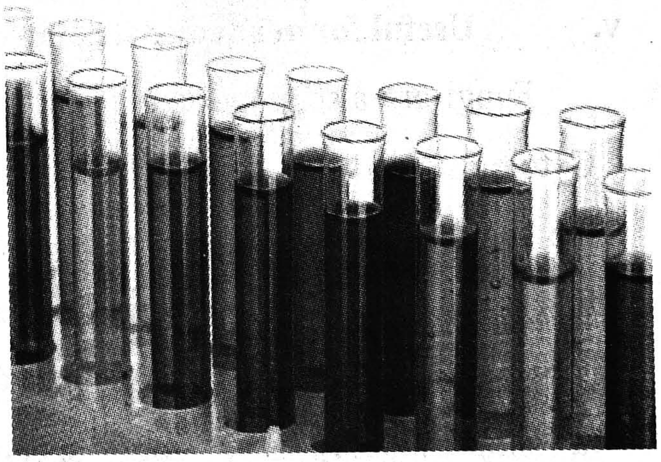
ii. In the production of enzymes, vitamins and hormones--

Amylase, a well known enzyme is produced from *Aspergillus niger* and *Aspergillus oryzae*. Digestin, Diastase, Ployzime etc. are obtained from *Aspergillus flavus*. For the enzyme invertase, *Saccharomyces cerevisiae* is used. All the yeasts including *Saccharomyces cerevisiae* are source of vitamin B-complex and Riboflavin. The fungus *Gibberella fujikuroi* is the source of a group of plant hormones used to accelerate the growth of many crops. The fungi from the most important basis of industrial processes involving fermentation such as the making of wines, beers, breads and the preparation of cheeses (from various type of yeasts and few *Penicillium* sp.)

iii. In the production of antibiotic substances, alkaloids and organic acids--

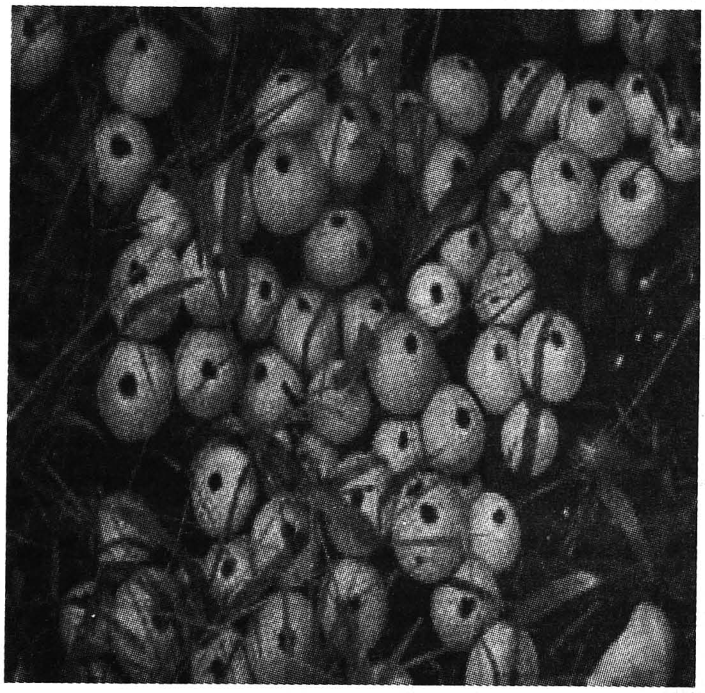
Most of the fungi produce enzymes, alkaloids and various other organic compounds as their metabolic products; Metabolic products are of great economic importance. One of the important metabolic products produced by fungi is the **Antibiotics**. Antibiotics either destroy or inhibit the growth of bacteria. Antibiotics produces by various fungi are used in the manufacture of drugs and also for other various purposes. In 1929, Sir Alexander Fleming for the first time established the fact that certain fungi could produce antibiotics. The most wonder drug 'penicillin' is an antibiotic substance extracted from *Penicillium_notatum*. Later on Raper (1952) extracted penicillin from *Penicillium chrysogenum*. Griseofulvin, one of the best-known antibiotics against fungal diseases of skin is obtainted from *Penicillium griseofulvum*. Another importent antibiotic 'chaetomin' is extracted from *Chaetomin cochliodes*. Many other antifungal and antibacterial antibiotics produced by *Armillariella mellea* in culture - these antibiotics are effective against Gram-positive bacteria and against some soil fungi such as *Trichoderma*. The various types of alkaloids obtained from fungi are also used as medicine. The sclerotia i.e., the so-called 'ergots' of the fungus *Claviceps purpurea* contain a number of alkaloids which are used for stops haemorrhage after child birth. A few organic acids are also produced from fungi. Citric acid and gluconic acids are produced from *Aspergillus niger*. *Rhizopus stolonifer* is used for the preparation of lactic acid and fumaric acid.

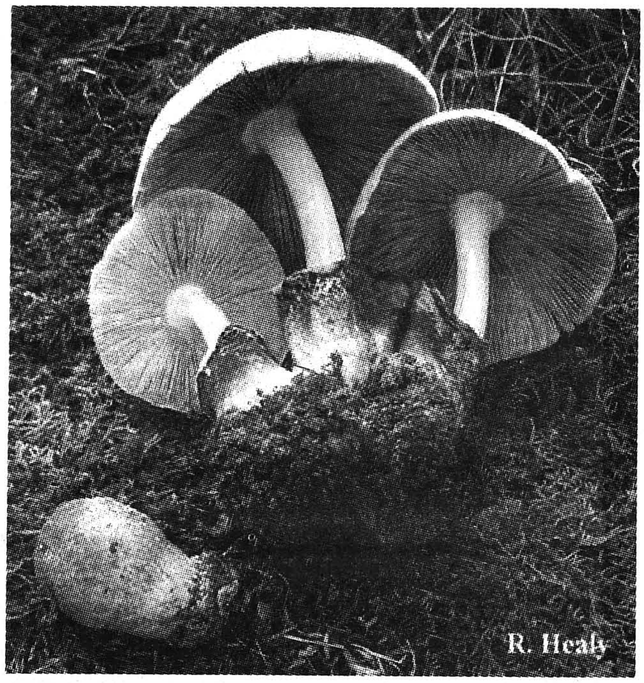




iv. Fungi used as food--

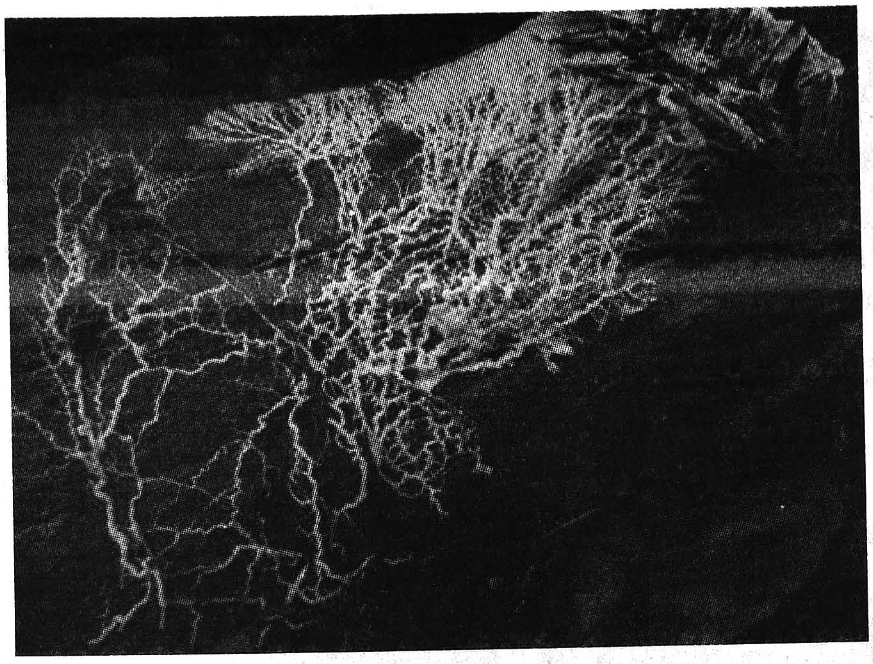
Some fungi e.g. 'mushrooms' (*Agaricus campestris*, *A. bisporus*, *Volvariella volvacea*, *Pleurotus sajar-caju*, etc.), 'morels' (*Morchella esculenta*) etc. are used as human food. *Agaricus bisporus*, species of *Volvariella*, *Pleurotus*, etc. are widely cultivated at the low cost of production and sold in the market as fresh mushrooms or canned and made into soup, sauces and other food products. Fructifications of some fungi, e.g, 'puff ball' (*Lycoperdon* sp.) are also edible when young. Well known yeast cake is obtained from *Saccharomyces cerevisiae* - yeast protein is called commonly 'single cell protein', and its protein is above 40%; yeast cake is produced from *Saccharomyces cerevisiae*. A popular food known as 'sufu' is produced from *Mucor*, *Antimucor*, etc.





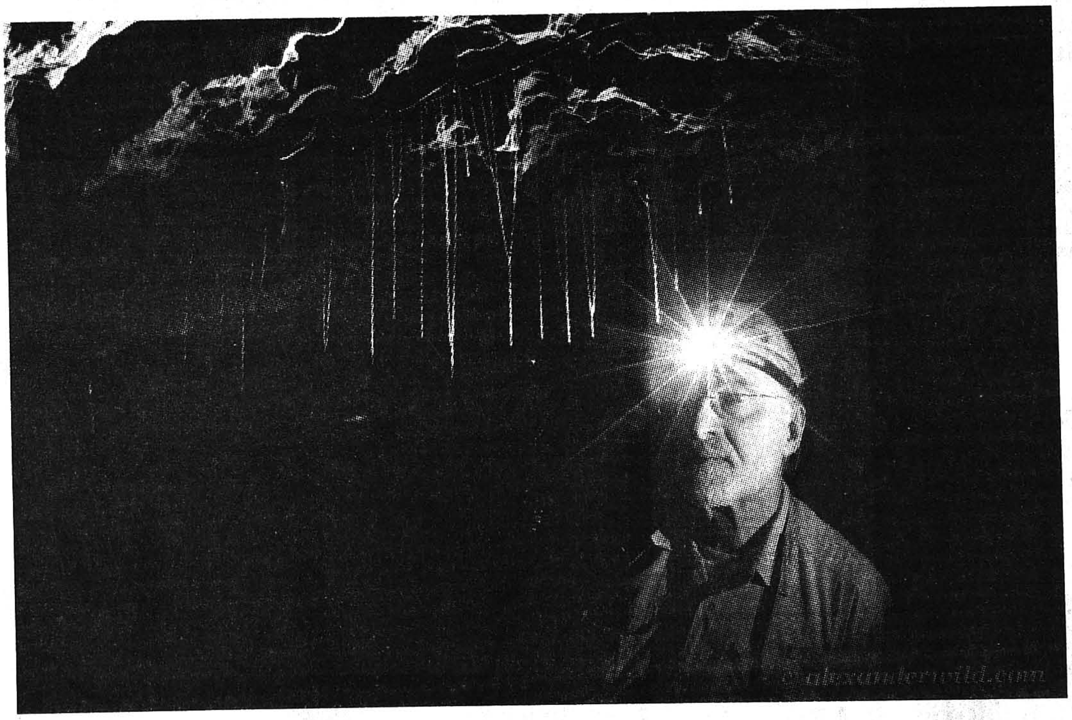
v. Useful for academic studies--

Fungi are also important from the viewpoint of academic studies. Genetics, Cytologists and Biochemists have found that fungi are important research tools in the study of biological processes. Cytological and genetical studies were made first on the fungus *Neurospora*. For the study of the laws of heredity, *Neurospora* is being used since 1920s. Rusch (1968) has shown that *Physarum polycephalum* (a slime mould) is a good specimen for the study of DNA synthesis, morphogenesis, mitotic cycle and other processes also.



vi. **In biological control of soil-borne pathogens and insects--**

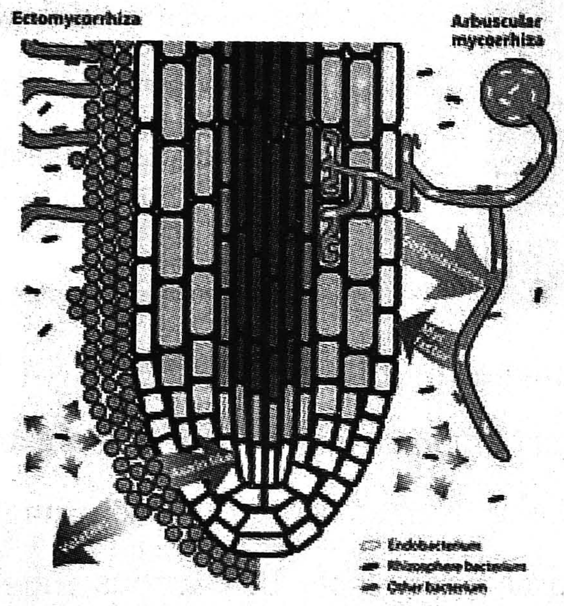
Some fungi (*Arthobotrys musiformis*, *Dactylaria thaumasia*, etc.) are known as predaceous fungi, because they parasitize *Amoebae*, Nematodes etc. - such fungi are used in large scale for controlling soil borne pathogens. Predaceous fungi possess a special sticky net works or sticky knobs for trapping and destroying such pathogens.

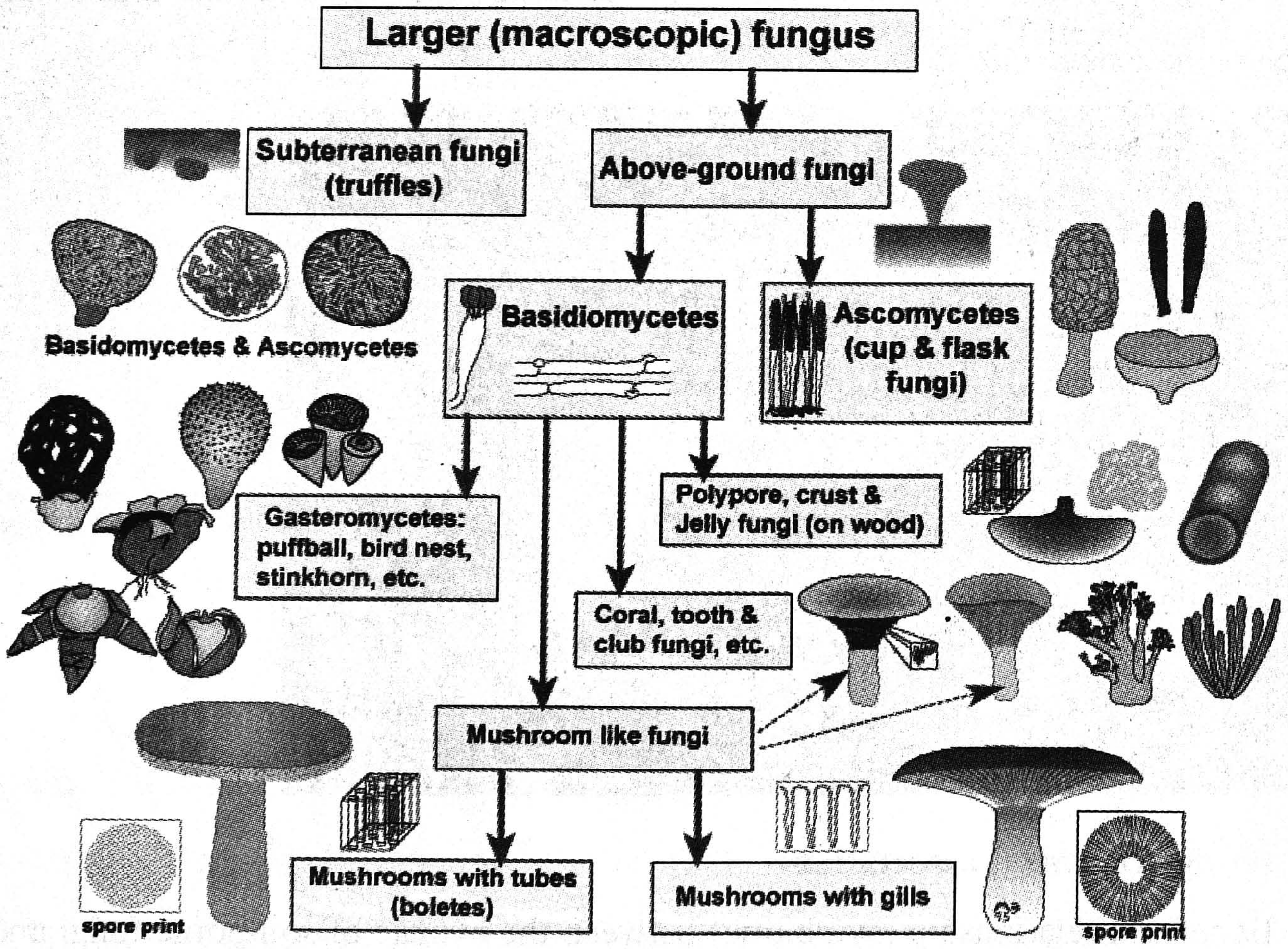


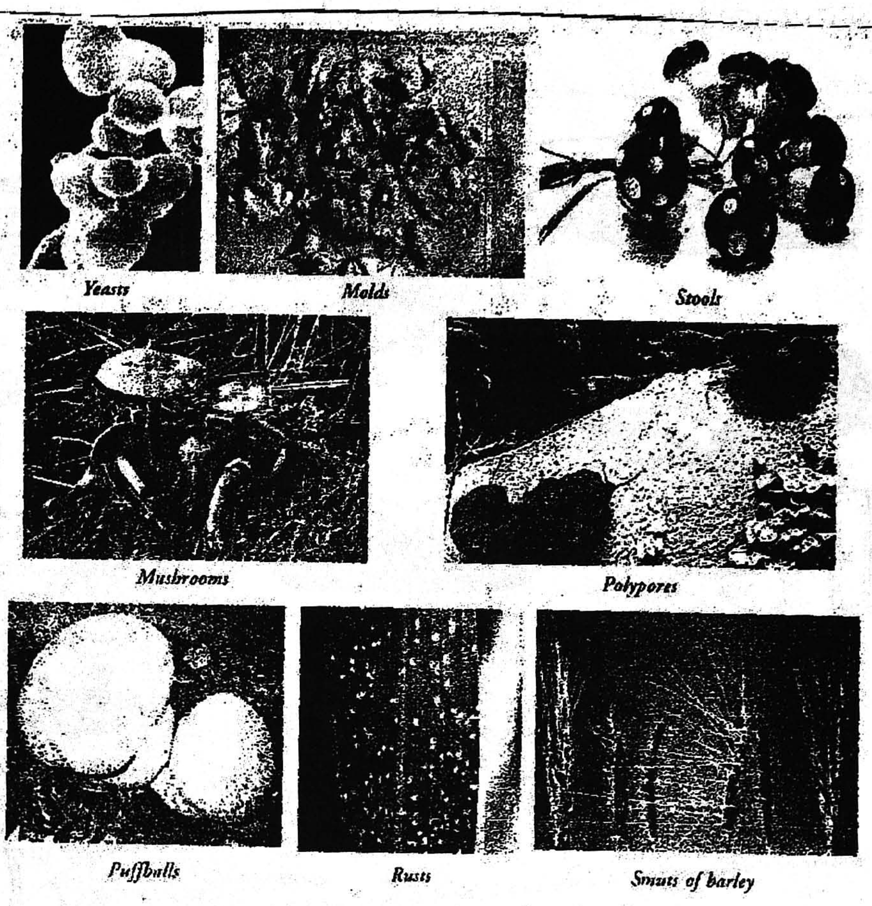
vii. **Mycorrhizal association--**

Beneficial relationship (symbiotic) between the hyphae of soil-borne fungi and the roots of higher plants is called Mycorrhizal association. Most of the deciduous or evergreen trees have ectomycorrhizas - in this case, the roots are externally

surrounded by the hyphae of some fungi as *Boletus*, *Phallus*, *Scleroderma*, *Amantia*, *Tricholoma*, etc. Those fungi decompose soil organic matter and the leaf litter. Ectomycorrhiza promotes the growth of the seedlings. Hyphae easily absorb nutrients like phosphorous, calcium, nitrogen, potassium etc. and then passed to the tissues of roots. In this way, a symbiotic relationship is established.







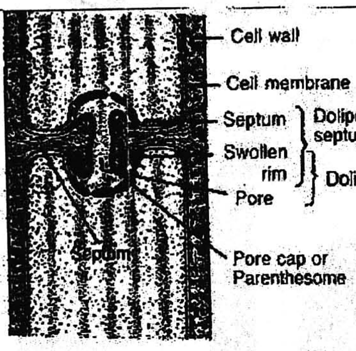
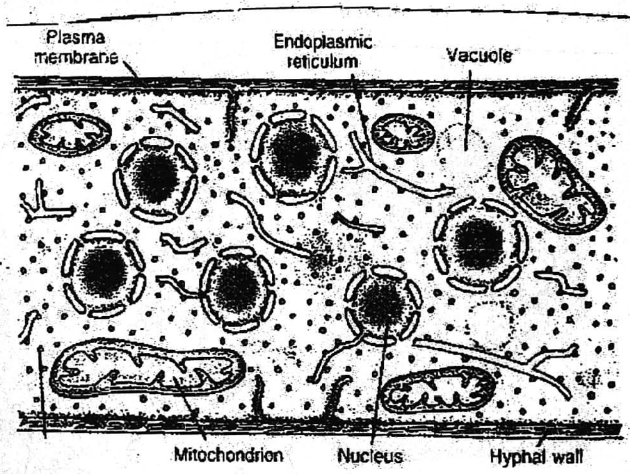
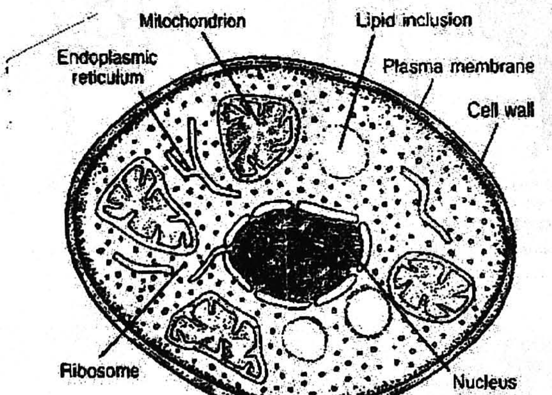


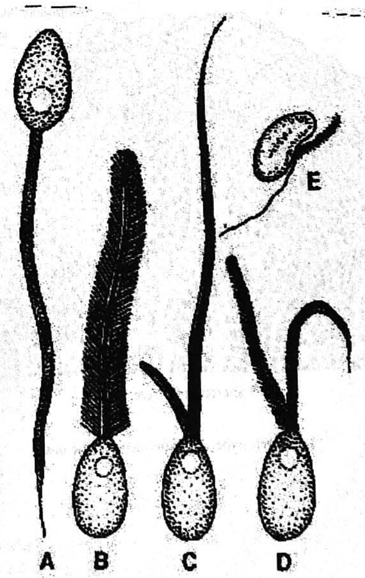
Fig. 1.7. *Fungi.* Annular septum of a basidiomycete with a doplipore septum.



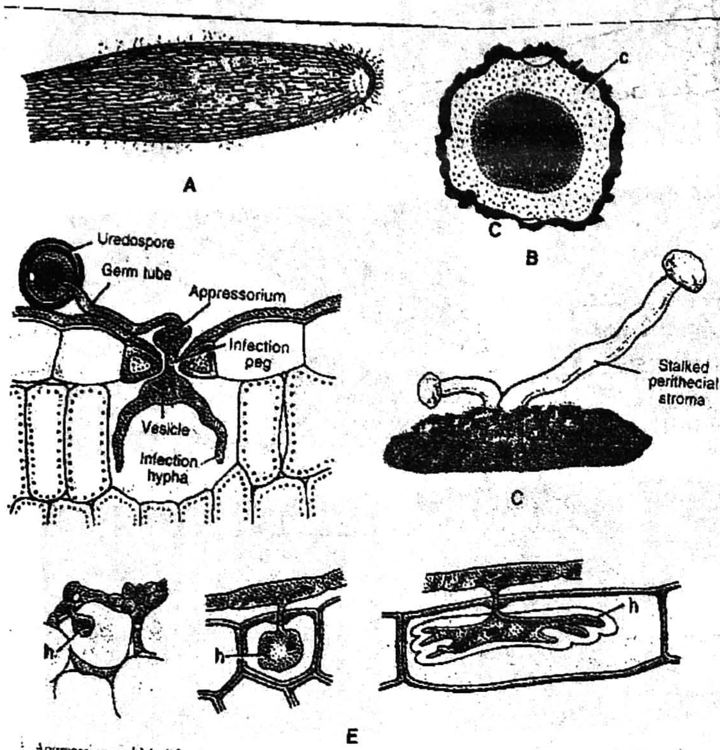
Fungi. Fine structure of a hypha near the growing tip of *Mucor* based on an electron micrograph.



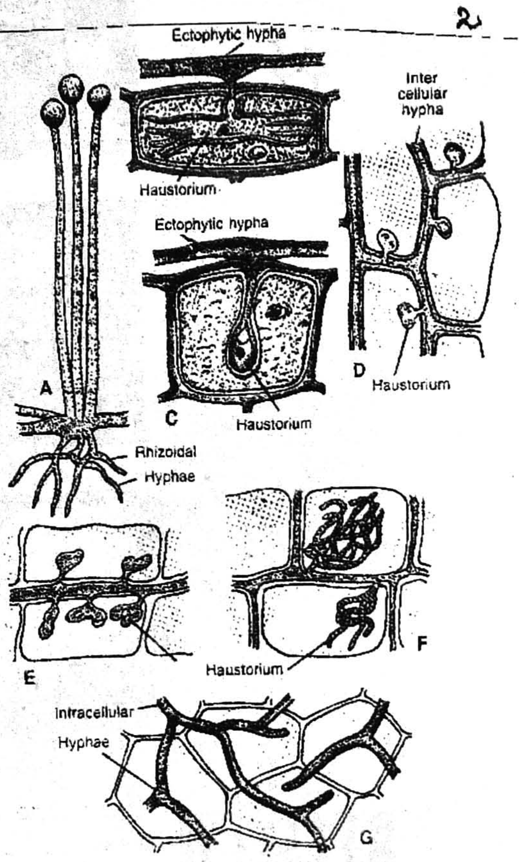
Fungi. Fine structure of Torula Yeast cell based on an electron micrograph.



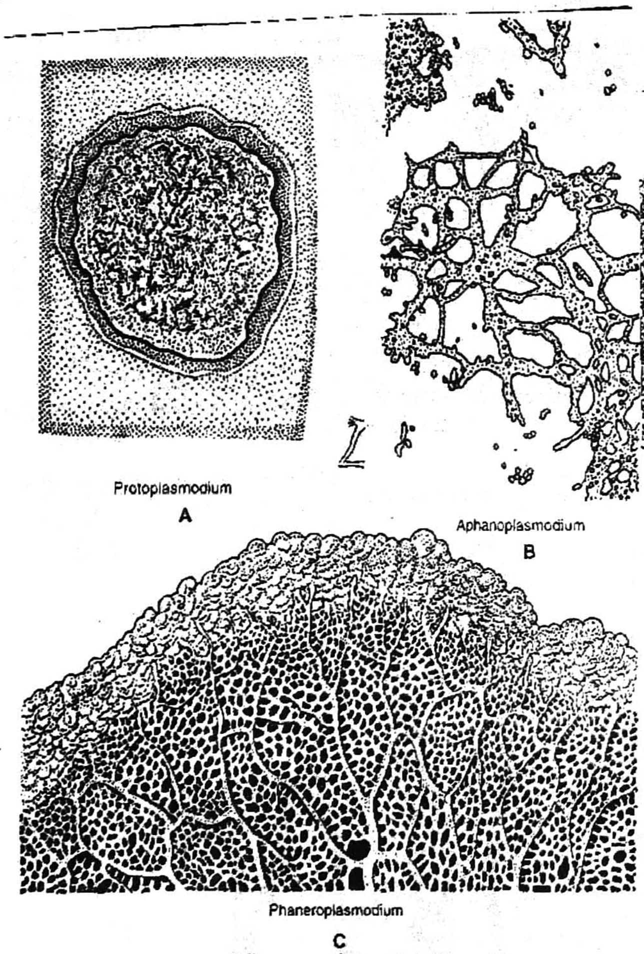
(A-D). Flagellation in the *Lower Fungi.*



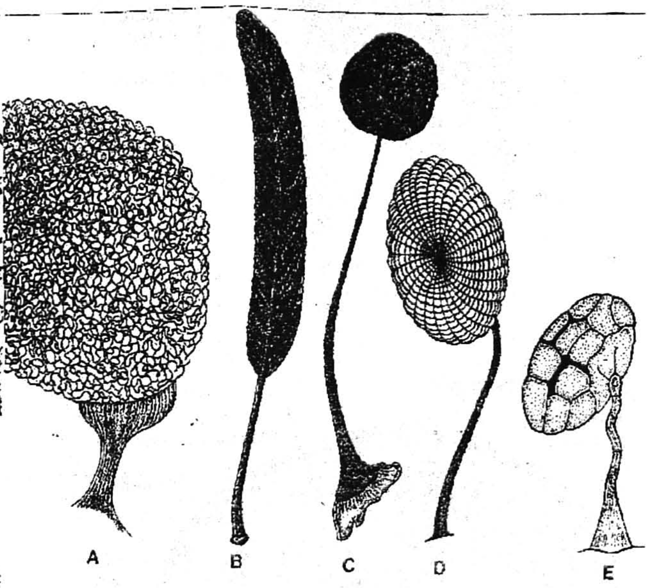
. Aggregation and Modifications of hyphae. A-B, Rhizomorph; C. Sclerotia; D, Appressorium; E. Haustorium.



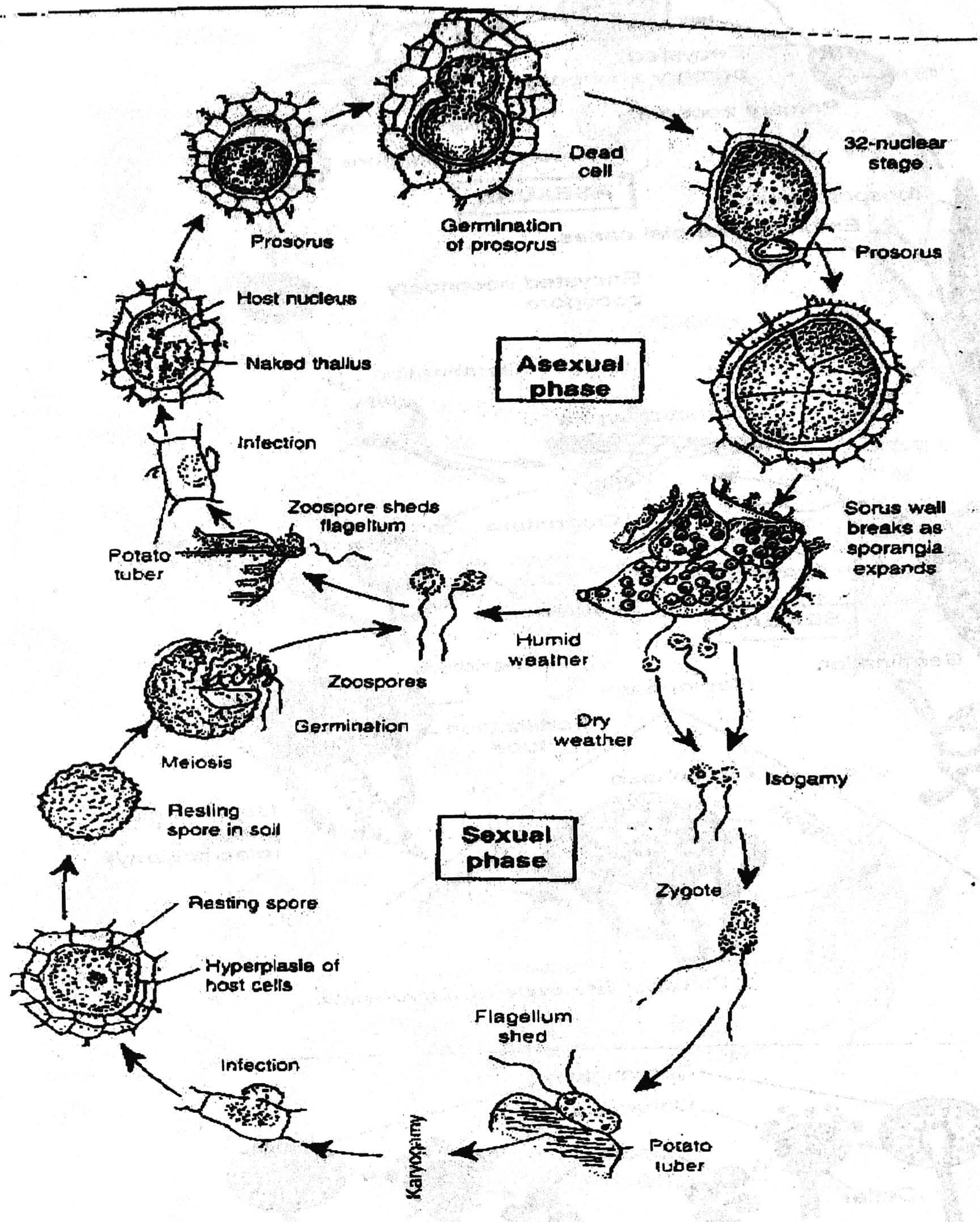
(A–G). *Fungi*. Modes of Nutrition. Explanation in the text.



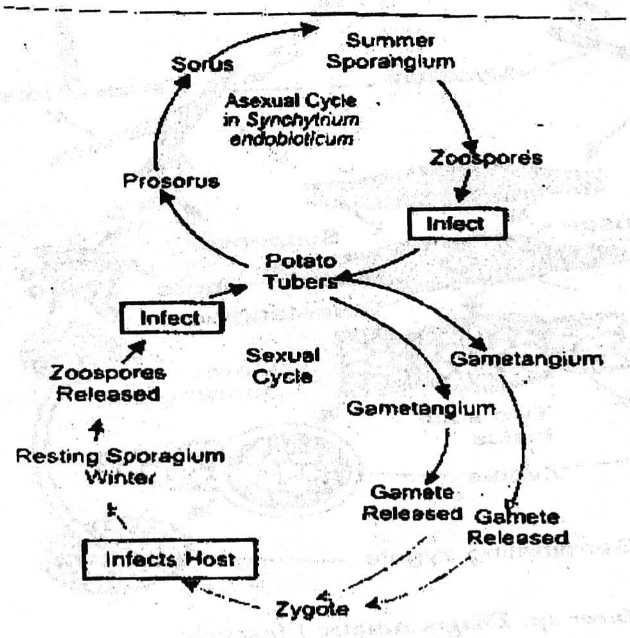
. Different types of Plasmodia in Slime molds



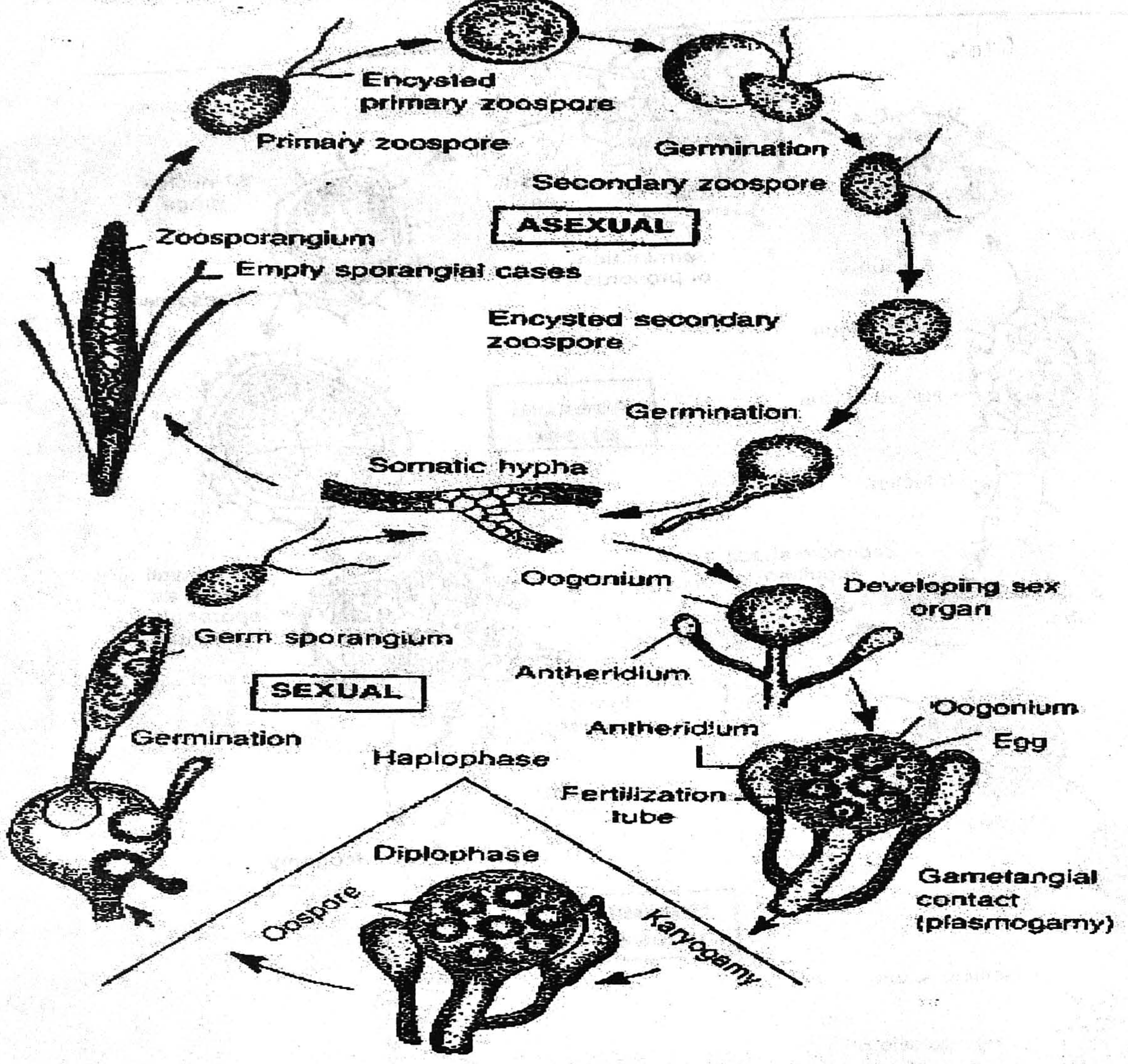
Different types of sporangia in slime molds : A. *Arcyria*; B. *Stemonitis*; C. *Comatricha*; D. *Didymium*; E. *Physarum*



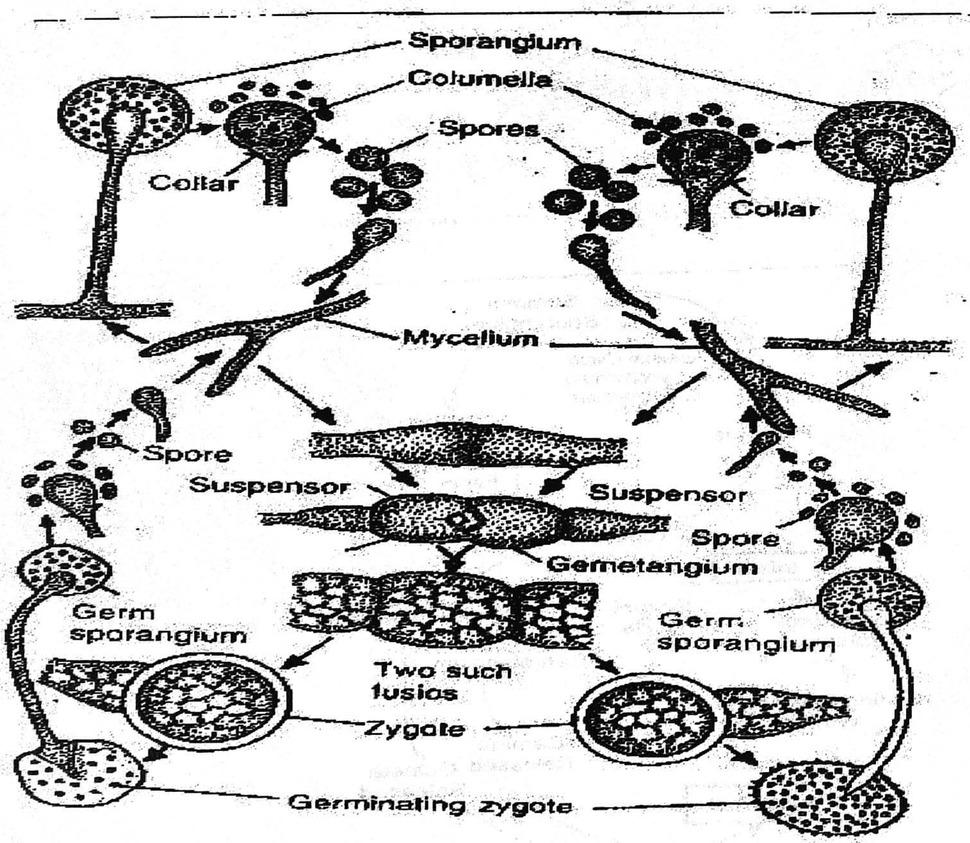
Pictorial life-cycle of *Synchytrium endobioticum*.



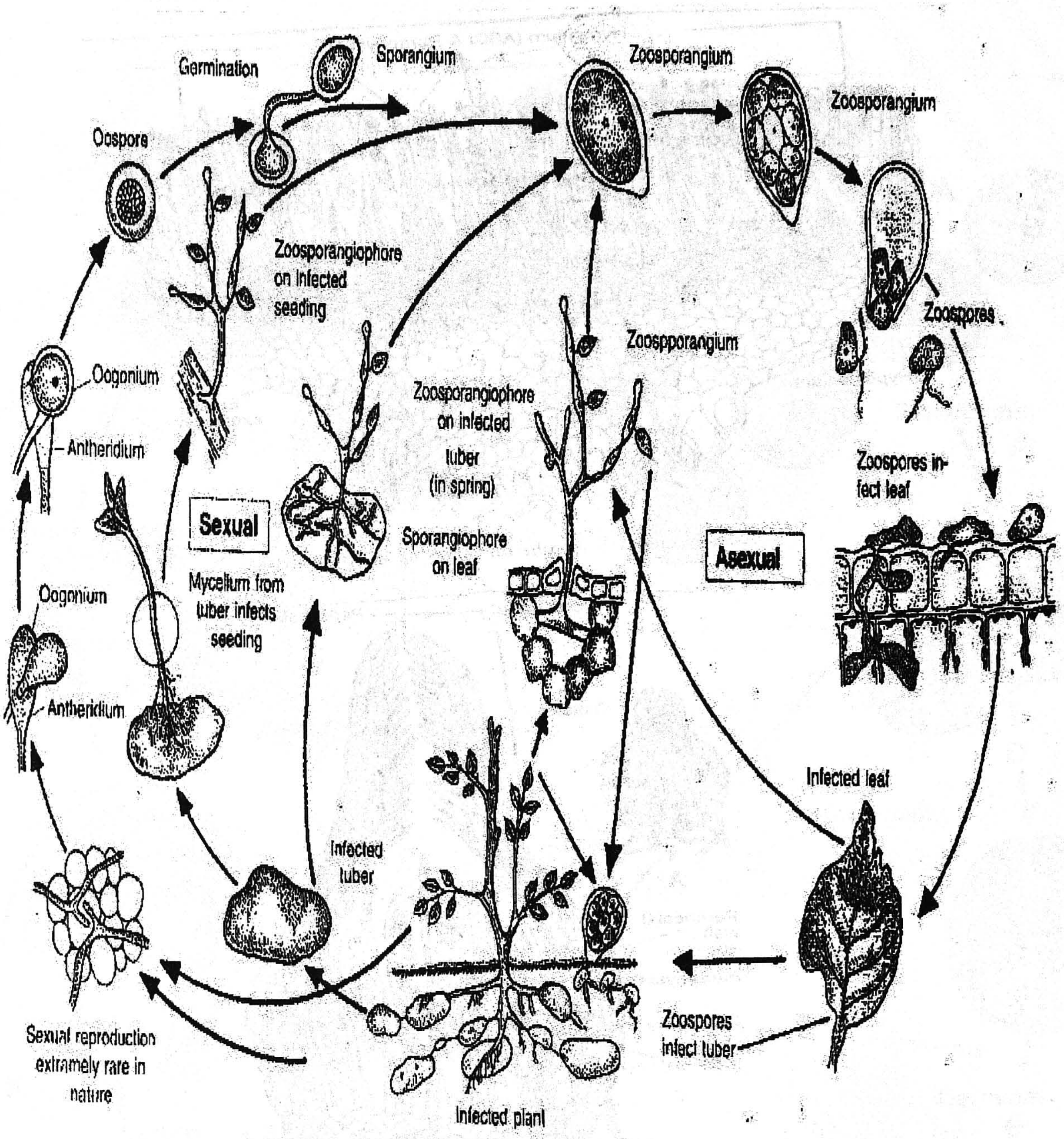
Word diagram of the life cycle of *Synchytrium endobioticum*.



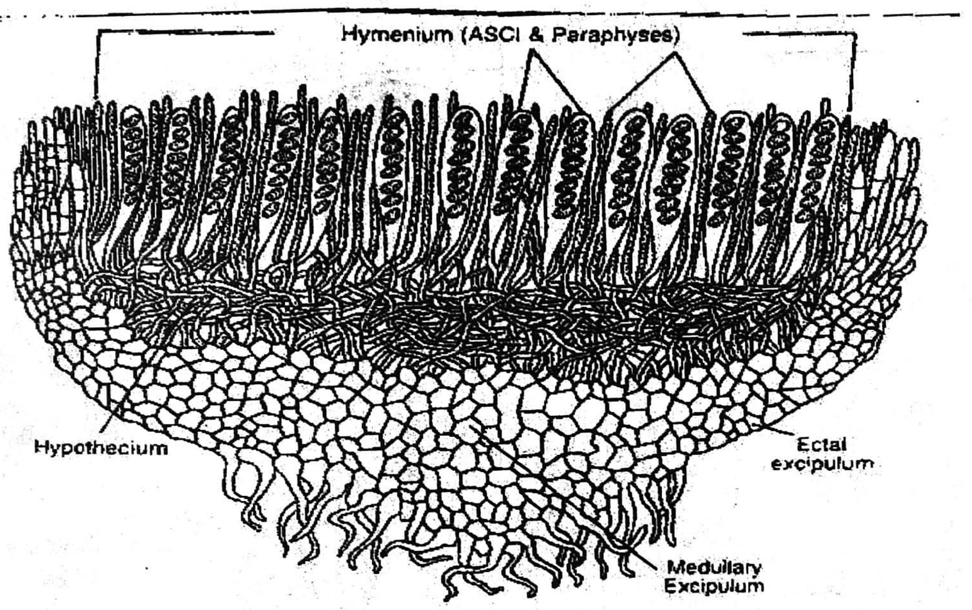
Pictorial life cycle of *Saprolegnia*.



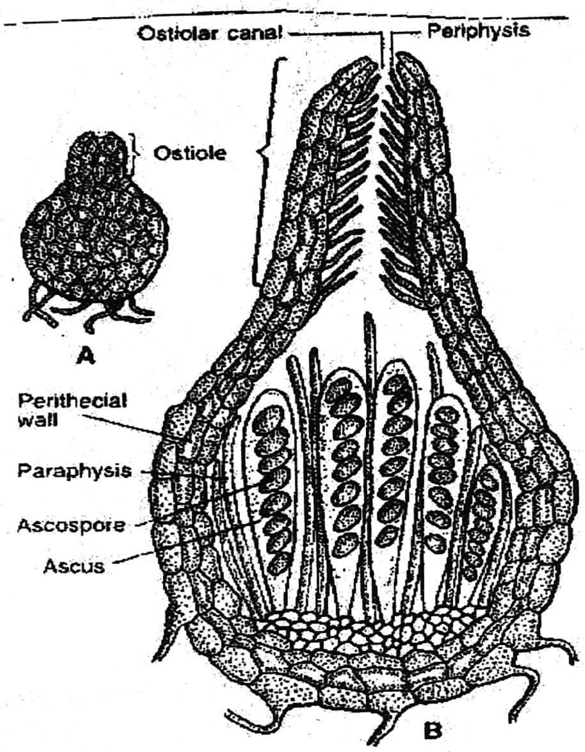
Mucor sp. Diagrammatic life-cycle



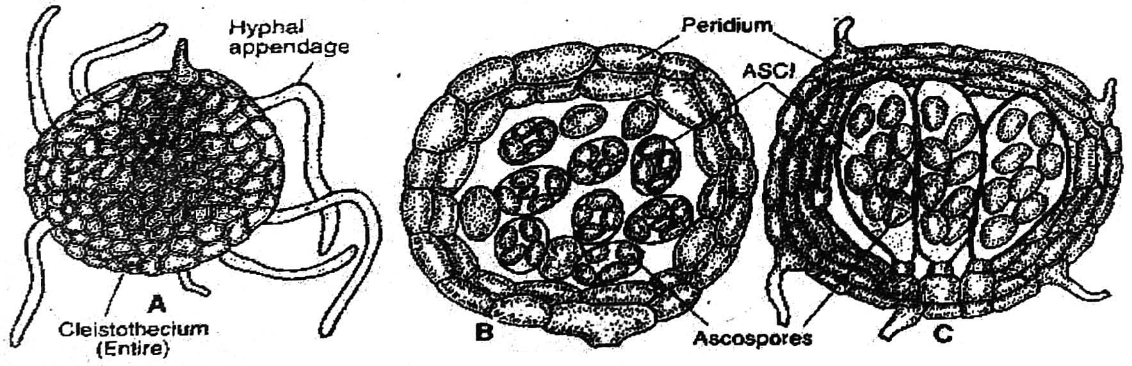
Pictorial Disease cycle of late blight disease of potato caused by *Phytophthora infestans.*



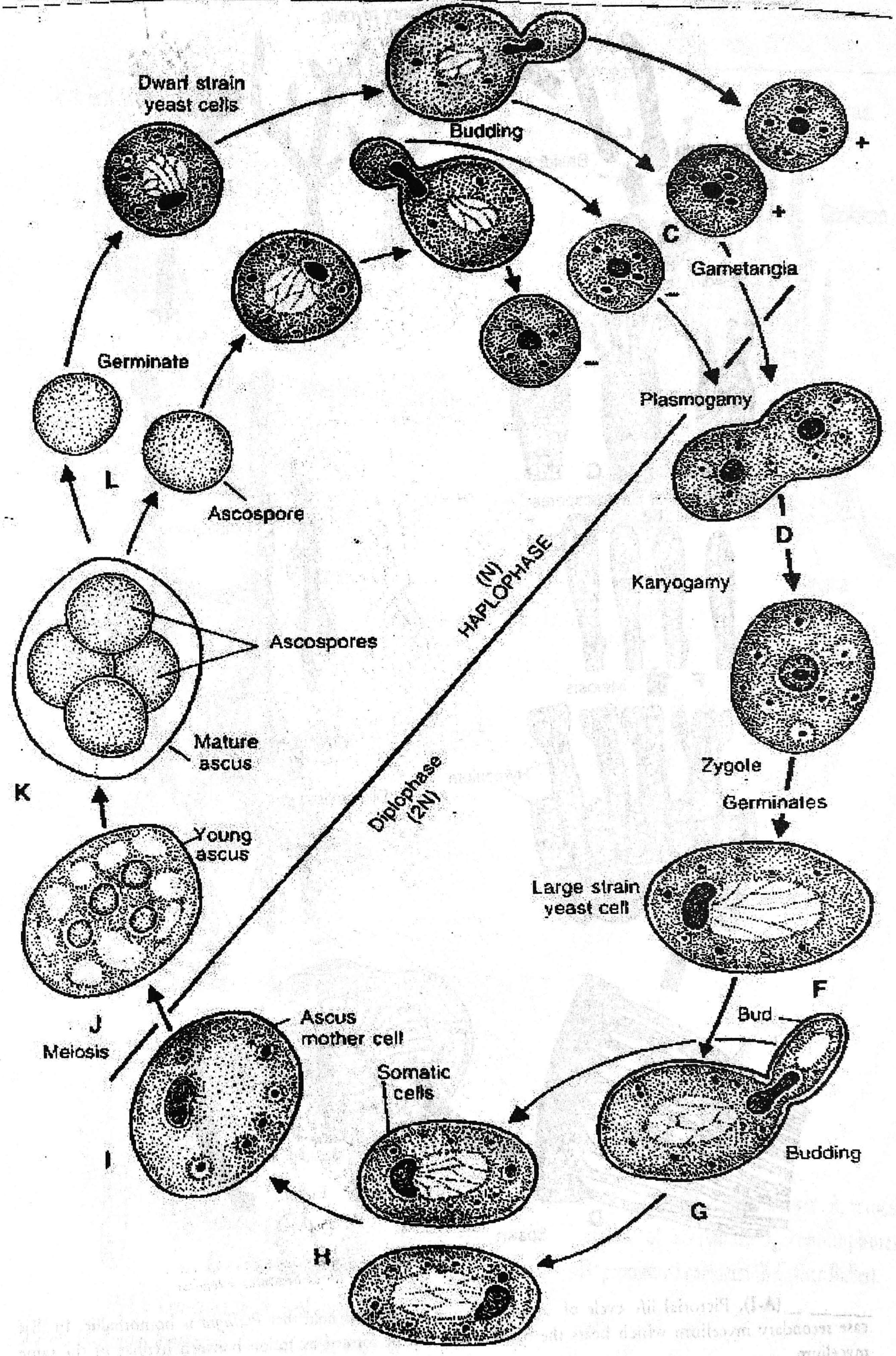
Ascomycetes. V.S. Apothecium showing structural details.



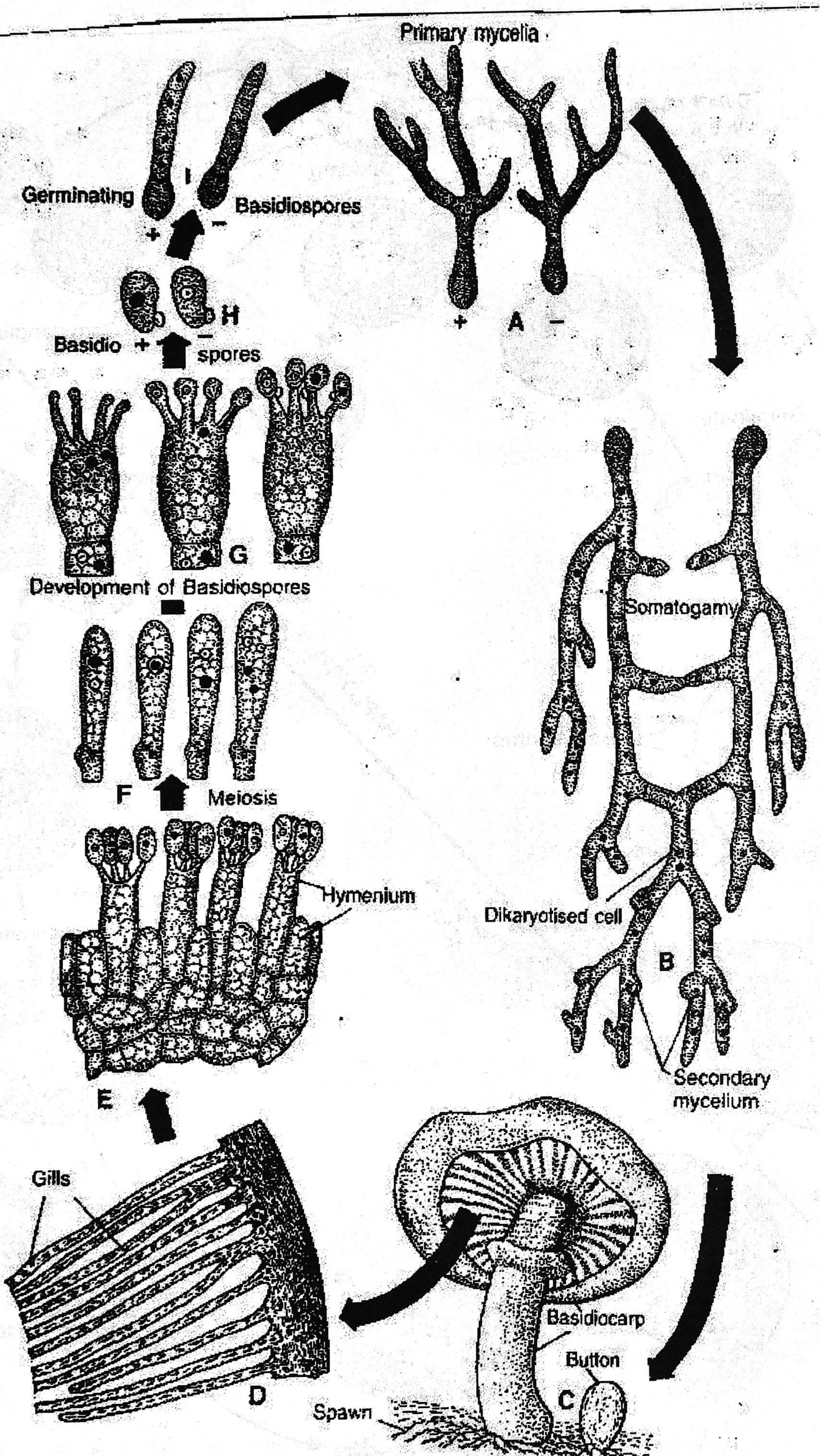
(A-B). Ascomycetes. A. Entire perithecium; B. V.S. perithecium showing structure.



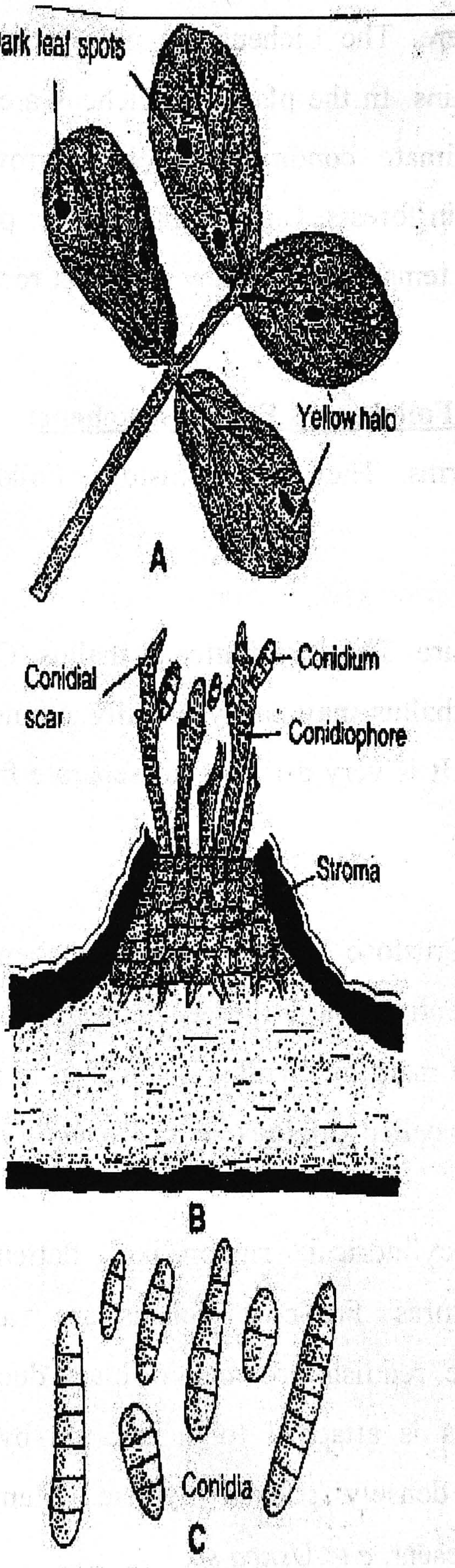
(A-C). *Ascomycetes.* A, Entire cleistothecium bearing hyphal appendages; B, section of a cleistothecium of *Aspergillus* with scattered asci; C. L. S. cleistothecium of *Erysiphe* with asci forming a regular layer.



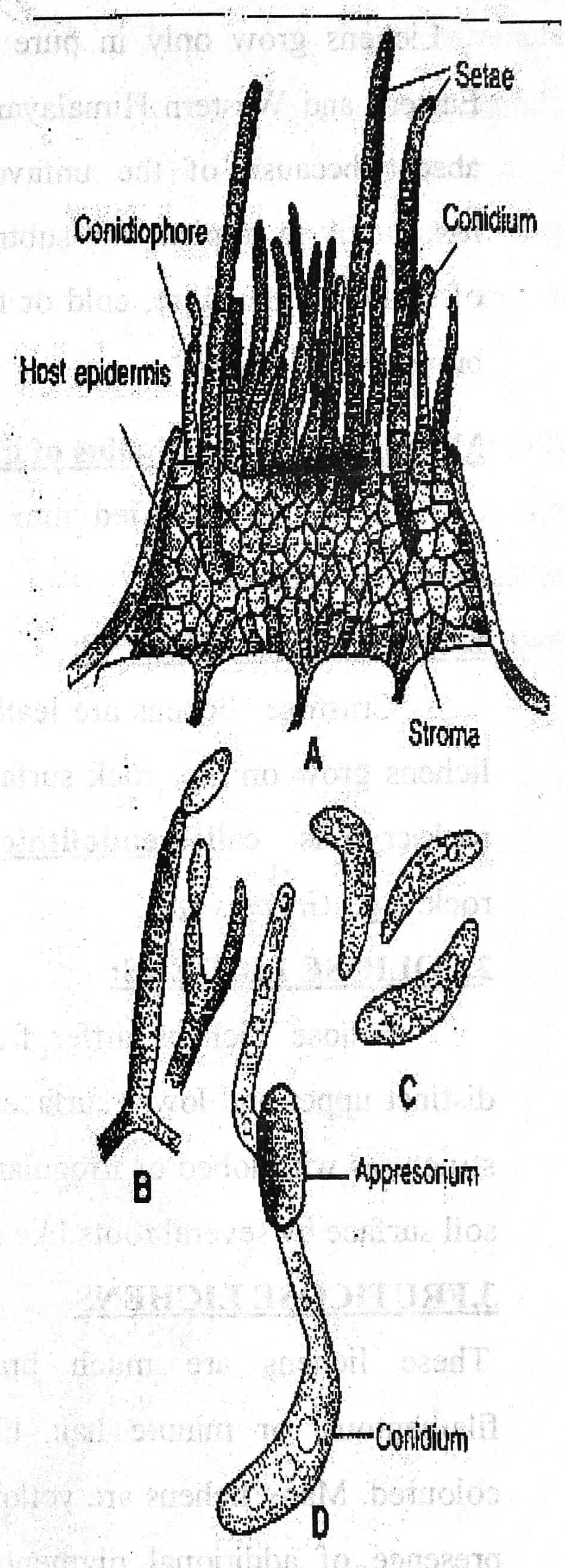
(A–L). *Saccharomyces cerevisiae.* Sexual Cycle.



(A-I). Pictorial life cycle of *Agaricus*. Some mycologists hold that *Psalliota* is homothallic. In that case secondary mycelium which bears the basidiocarps will be formed by fusion between hyphae of the same mycelium.



(A-C). *Cercospora sp.* A, Leaf spots on the leaflets of *Arachis hypogea;* B, L.S. acervulus with the geniculate conidiophores emerging; C, conidia.



(A-D). *Colletotrichum sp.* A, vertical section of acervulus; B, conidiophores; D, germinated conidium (B-C after Buller).

Lichens – General account; Economic importance:

Occurrence:

Lichens grow only in pure atmosphere. The Lichens are more common in Eastern and Western Himalayan mountains. In the plains the lichens are almost absent because of the unfavorable climate conditions. Lichens grow most luxuriantly in tropical and subtropical rain forests. Lichens grow in the presence of sufficient moisture, cold or moderate temperature. They grow on rocks, tree branches and leaves.

Morphology of the thallus of Crustose, Foliose and Fruticose lichens:

Lichens are classified into three forms. They are Crustose, Foliose and Fruticose lichens.

1.CRUSTOSE LICHENS:

Crustose lichens are leathery texture. They are flattened thallus. Crustose lichens grow on the rock surface. The thallus may partly or fully submerge on rock crystals called **endolithic** lichens. It is very difficult to separate from the rock. e.g.. *Graphis sp.*

2.FOLIOSE LICHENS:

Foliose Lichens differ from the Crustose Lichens. Foliose lichens have distinct upper and lower surfaces (dorsiventral).The Foliose lichens are leaf-like structures with lobed or irregularly folded margins. Thallus is attached to rock or soil surface by several roots like structures called **rhizines.** *e.g., Parmelia sp.*

3.FRUTICOSE LICHENS

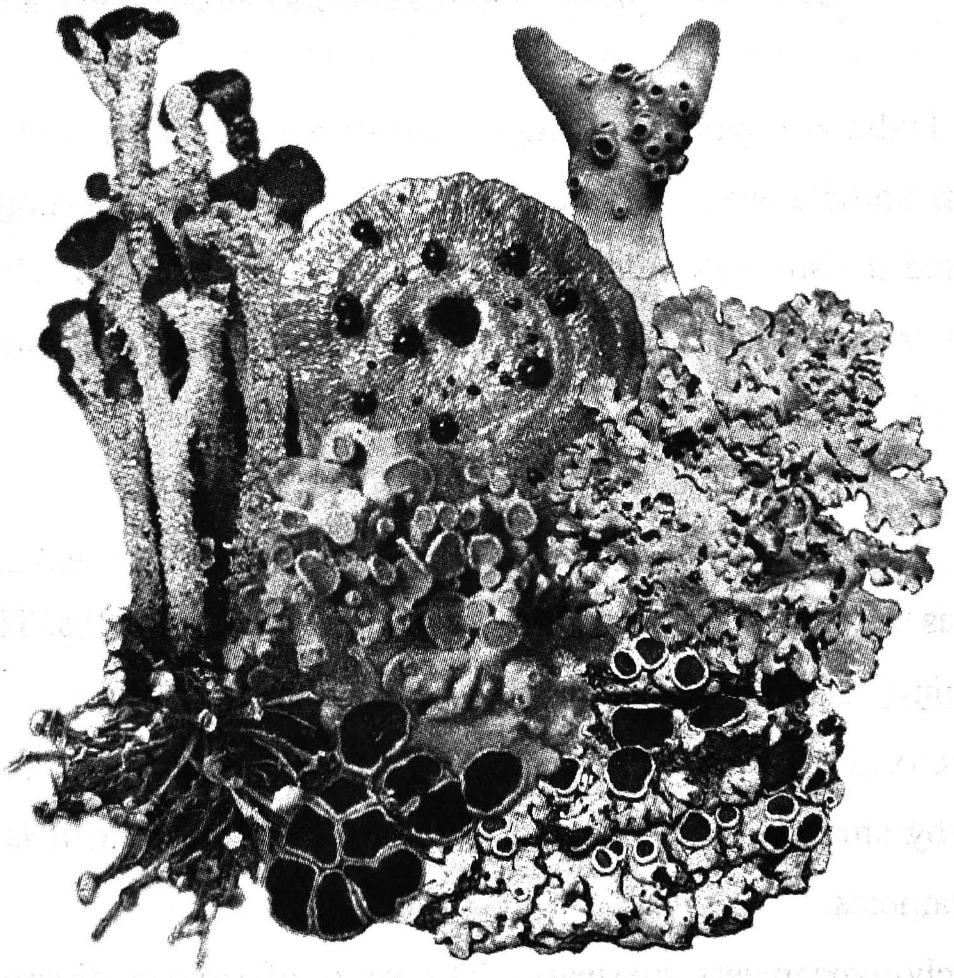
These lichens are much branched, cylindrical, ribbon-like, flattened or filamentous, or minute hair like structures. Fruticose lichens are variously coloured. Many lichens are yellow, orange, reddish, brownish or black due to the presence of additional pigments. Thallus is attached to substratum by basal rhizoidal strands. It is composed of densely packed hyphae. Many cup like(**Apothecia**)reproductive bodies are present. *e.g., Usnea sp.*

Fungal components, Algal components and Symbiosis:-

The Lichen thallus is composed of two organisms. They are **Mycobiont** (fungal component) and **Phycobiont** (algal component).

The fungal component of lichens is a member of Basidiomycetes or Ascomycetes. Such lichens are called Basidiolichens and Ascolichens. The basic fungal element is the hypha or mycelium. The wall of the hypha is multilaminate (many layers) . The cells are highly vacuolated. The plasmalemma is invaginated.. The cytoplasm is granular. The algal component of lichens is a member of Myxophyceae (blue green algae) or Chlorophyceae (green algae). The algae may be filamentous or non-filamentous. Basidiolichens aalways possess a member of Myxophyceae. Lichen algae are completely surrounded by fungal tissue.

The gelatainous crustose lichens have algal and fungal components uniformly distributed. Such lichens are not differentiated into layers of tissues. They are called homomerous lichens. The folisoe and fruticose lichens are differentiated into several layers of tissues such as upper cortex, algal zone, medulla and lower cortex.. They are known as heteromerous lichens.



Symbiosis is the intimate biological union of two different organisms. Lichens are the best examples of symbiosis. A lichen is an intimate association of a fungus and an alga. The partnership (**consortium**) between a fungus and an alga is of symbiotic nature. The alga synthesizes and supplies food material to the fungus. Fungal hyphae absorb water and mineral nutrients and supplies to the alga. This type of symbiosis is known as **heliotism**,(=master and slave). According to some authors, the fungal-algal partnership is of **parasitic nature**. In many lichens the haustoria from the fungus penetrate into the algal cells. This is a very strong point in support the relationship between fungus and alga is of parasitic nature.

Vegetative reproduction:-

It takes place by following methods:

1. Fragmentation: On maturity the older portions of the thallus of lichens die and decay or the thallus breaks into pieces accidentally. Each piece develops into a new Lichen thallus. These types of fragmentation more frequently occur in fruticose lichens.

2. Isidia and Soredia: Isidia are cylindrical finger-like structures. Isidia contain algal and fungal tissues. Soredia are separable clumps of a few algal and fungal cells. Shading , increased moisture stimulate isidia and soredia formation. They easily broken off and transported to other places and grow into new lichen thallus.

Sexual reproduction:

In Ascolichens the female reproductive organ is called Ascogonium or Ascogonial coil. It acts as the female element. It is a long multicellular hypha. The coiled base is the Oogonium. and the straight portion above is the trichogyne.

The male reproductive organ is called Spermagonium or Pycnium . It is flask-shaped cavity. It opens by small ostiole. The spermatia are male element. It is a small non-motile male gametes.

Fertilization: The trichogyne meets spermatia. The walls of contact dissolve and the male nucleus gradually passes downward to the Oogonium. It fuses with the female nucleus of the egg. As a result zygote is formed.

The zygote develops into Apothecium. It is a fruiting body. It is small cup-like or disc-like structure embedded on the surface of the lichen thallus. It consists of an upper and a lower cortical layer with medulla, in between. Algal components are also present. The surface of the disc is the fertile part. It is lined by the **Hymenium**. Hymenium consists of **Asci and paraphyses**. Each ascus contains eight Ascospores.

Ascospores are discharged during moist weather. Spores germinate and produce branched hyphae in all directions. It comes in contact with a suitable alga. Wind, water or animals are helpful for contact. Combined growth of the fungus and the alga results in a new lichen formation. Further differentiation into a cortex, algal layer and medulla are occurred by the end of second year. Lichenization must be a highly selective process. In absence of a suitable phycobiont , the branched hyphae dies.

Lichen as Pollution monitors:-

Lichens are sensitive to man-made atmospheric pollutants. There are no protective structures such as a waxy cuticle or stomata on the lichen thallus. Toxic metals in the atmosphere are absorbed very efficiently over the entire surface of the lichen thallus. Air pollution kills off all lichens or result in a poorer and altered community. Lichens disappeared in many metropolitan and industrial areas. Lichens can be used to biomonitor levels of Sulphur di oixide and a number of toxic metals. SO_2 is a by-product of automobile exhaust. SO_2 was the prime phytotoxin affecting lichens. The amount of damage to the lichens can be correlated with measurements of SO_2. Acid rain reduces the pH of lichen thalli and affect metabolism.

Lichen absorbs lead and accumulates in fungal tissues. Lichens are excellent biomonitors of lead fallout from automobile exhaust along highways. Fluorides, Nickel, Mercury and Zinc is by-products of many industrial and electric generation plants. They are also readily accumulated by algal cells and fungal components of lichen thallus and affects their physiology.

There are three ways to monitor air pollution.

1. By estimating pollutants accumulated in lichen thallus, we can find out the type, presence, location and transport distance of the pollutants.
2. To map all lichen species around a pollution source to measure the effect, intensity and distribution of pollution by recording their presence or absence.
3. To transplant healthy lichens into polluted areas for measuring pollution.

Economic importance of Lichens:

1. Food for man and animals:

In Tamilnadu ,foliose lichen, *Parmelia sp.* has been used in curry preparation.

In Iceland *Cetraria islandica* is mixed with wheat flour.

Travelers in arctic region have eaten leathery lichen Umbilicaria.

In Western Asia and Northern Africa, two species of *Lecanora* are used as vegetable diet.

Cladonia is a food for reindeers and cattle in cold regions.

2. Medicinal importance:

Usnic acids produced from many lichens have antibiotic properties. They are effective against many Gram-positive bacteria.

Many antiseptic creams, such as '*Usno*' and '*Evosin*' have tumor-inhibiting and virucidal properties.

'*Erythrin*' obtained from *Roccella montagnei,* is used for serious heart disease.

Some lichen compounds (*lichenin* and *isolichenin*) have *anti-tumour* properties.

Lobaria pulmonaria was used for the tuberculosis and other lung diseases.

Some lichens are used with tobacco because of their hallucinogenic effects.

Peltigera canina, the dog lichen was used as medicine for hydrophobia in ancient days.

Letharia vulpina is used as a poison. Vulpinic acid, present in this lichen, is responsible for its poisonous nature.

3.Chemical uses:

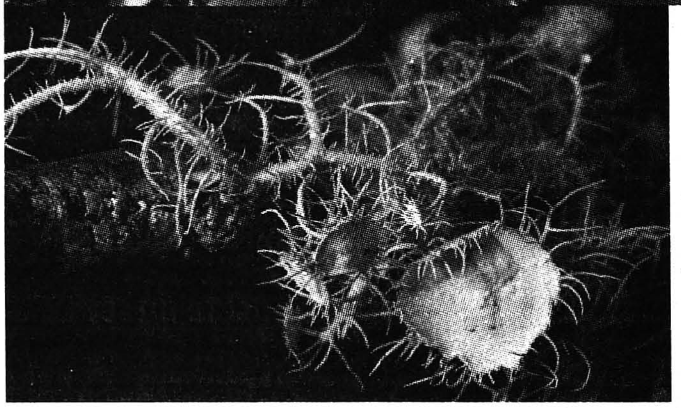
Lichen was also used in tanning, in perfumery and as a substitute in brewing.

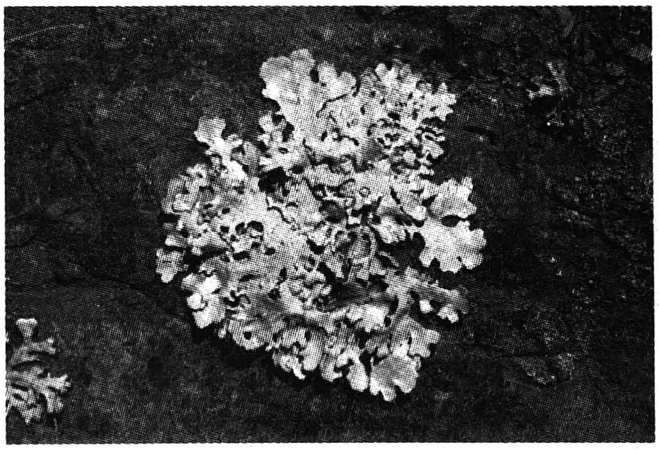
Evernia prunastri , yields an excellent perfume.

Species of *Rocella* ,*Parmelia* and *Lecanora* are used in colouring woolen and silk fabrics.

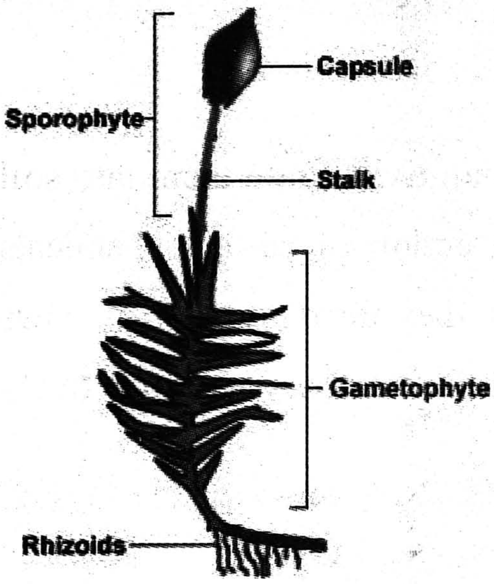
4. Ecological importance:

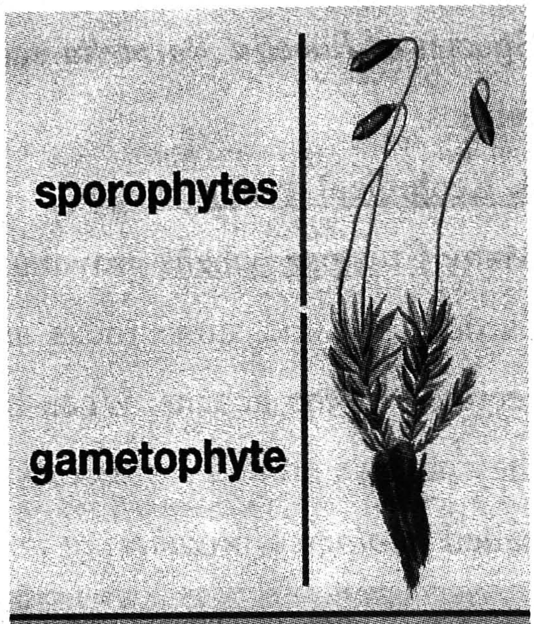
Many Crustose lichens growing on rocks dissolve and disintegrate them into soil particles. Lime stone rocks are dissolved by the action of certain chemicals secreted by the lichens. When lichens die and decay they form humus soil. Thus they prepare ground for succession of vegetation. These activities are collectively called '*biological weathering*'.



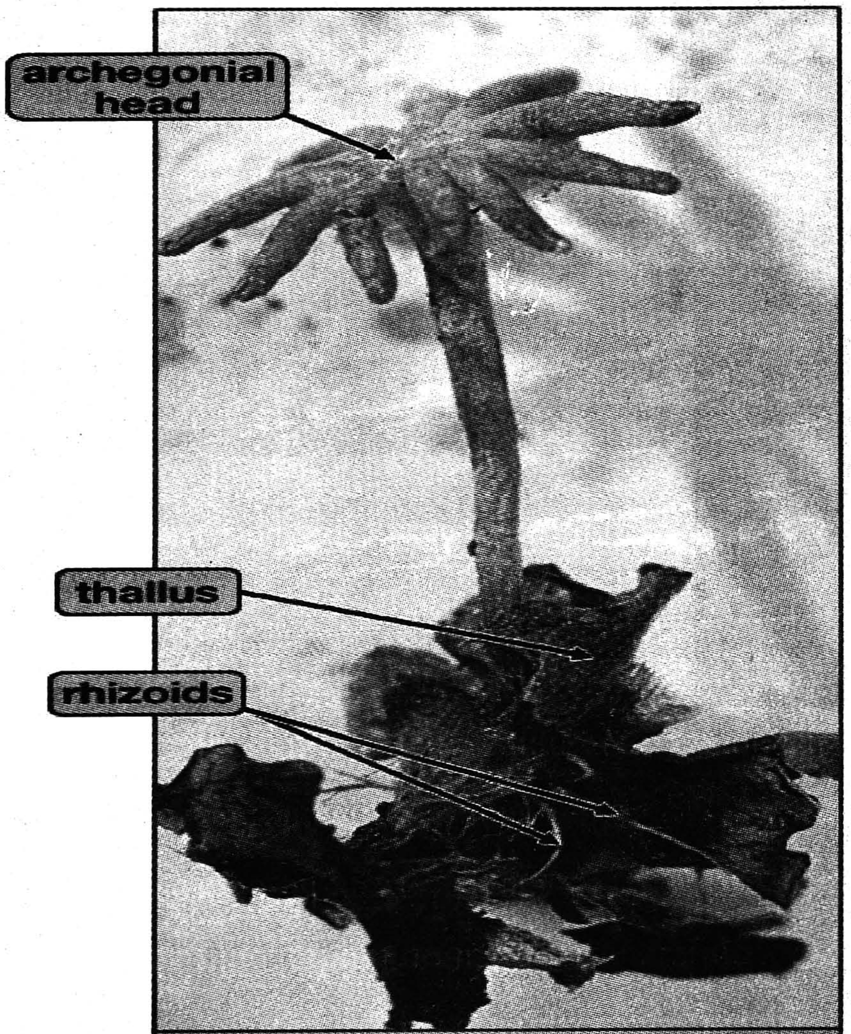


Bryology: Morphology, structure and reproduction: distribution-Classification; Characteristic features of Hepaticopsida, Anthocerotopsida and Bryopsida. Ecological significance; Economic importance.

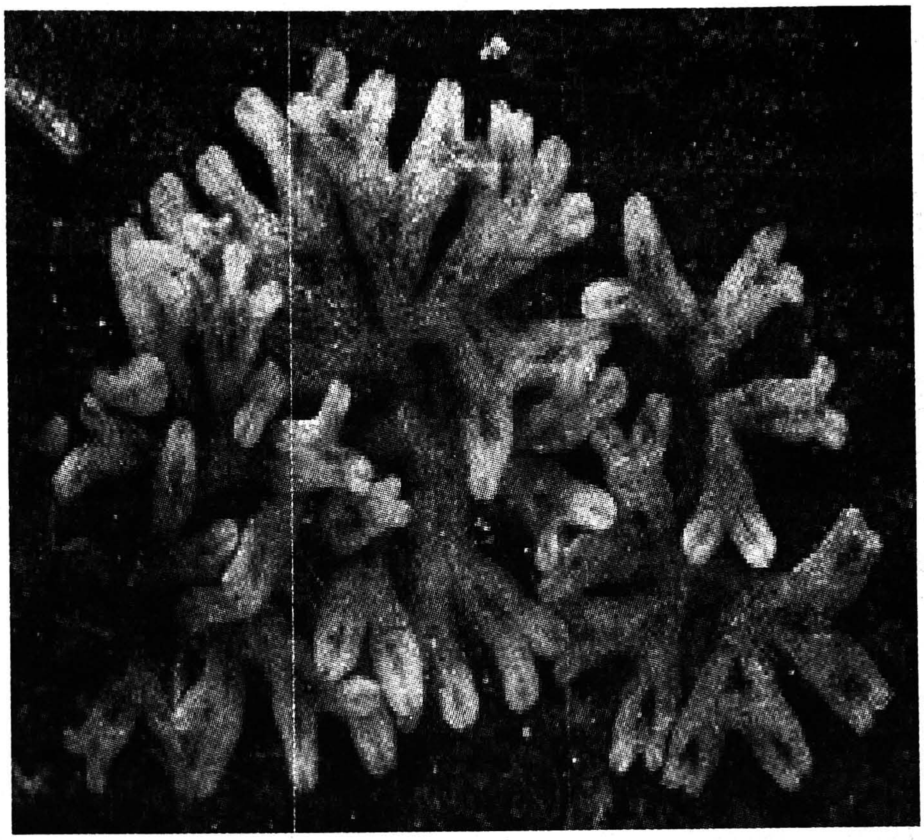


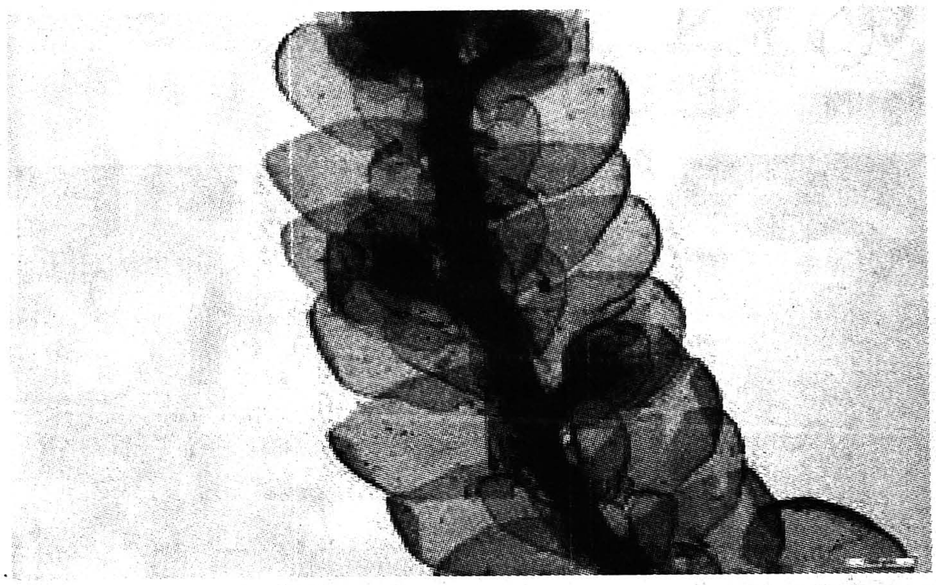


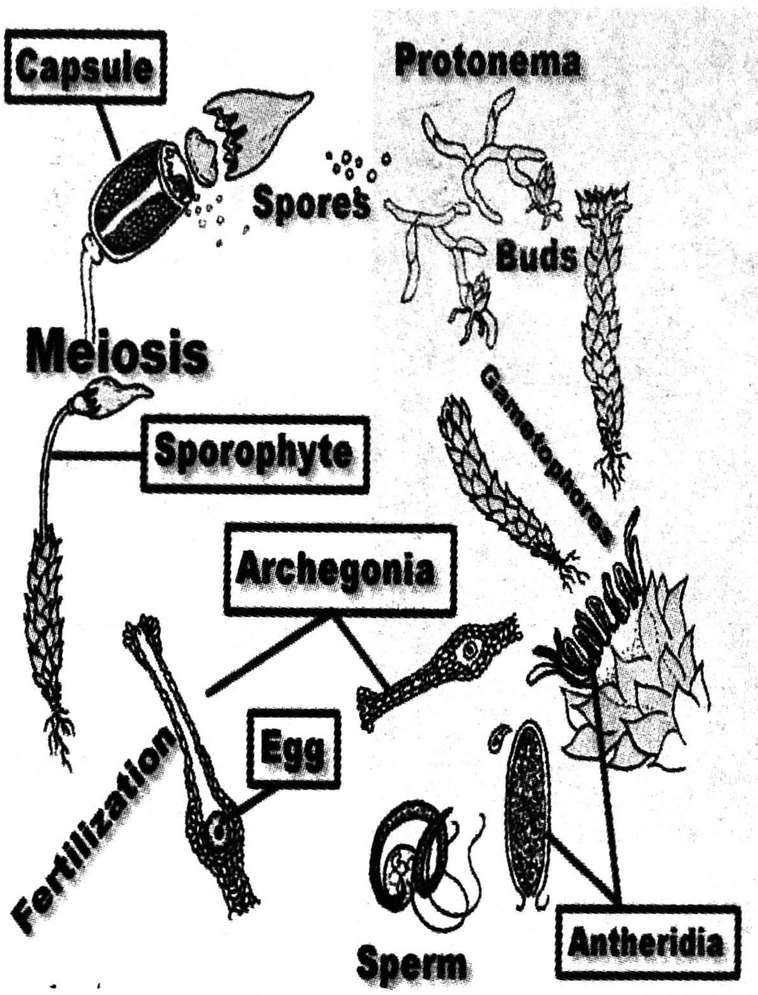
Mnium

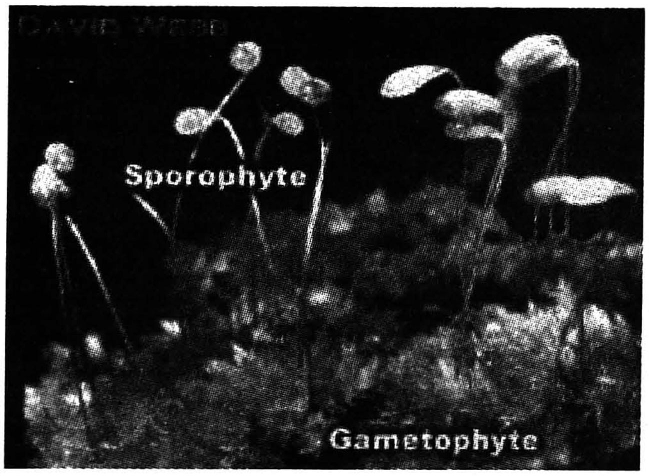


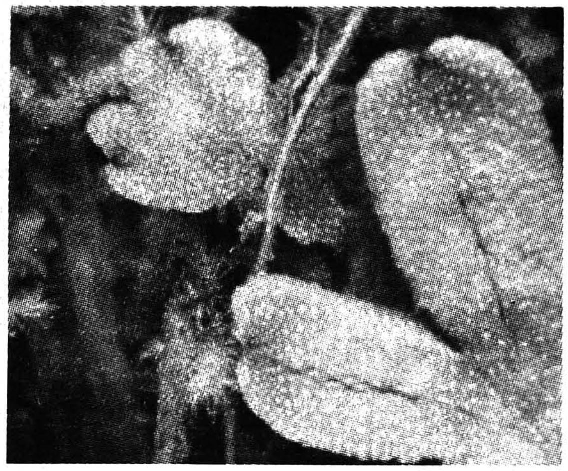
Marchantia, a liverwort

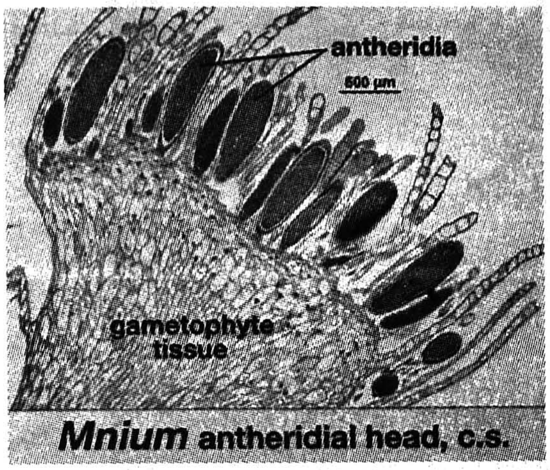


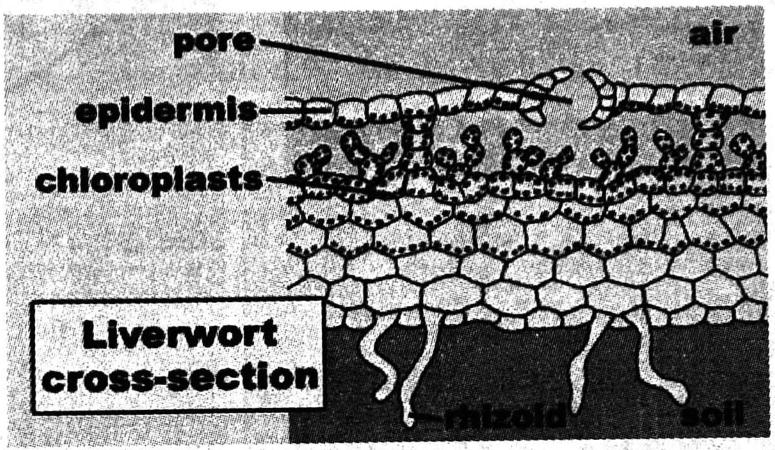


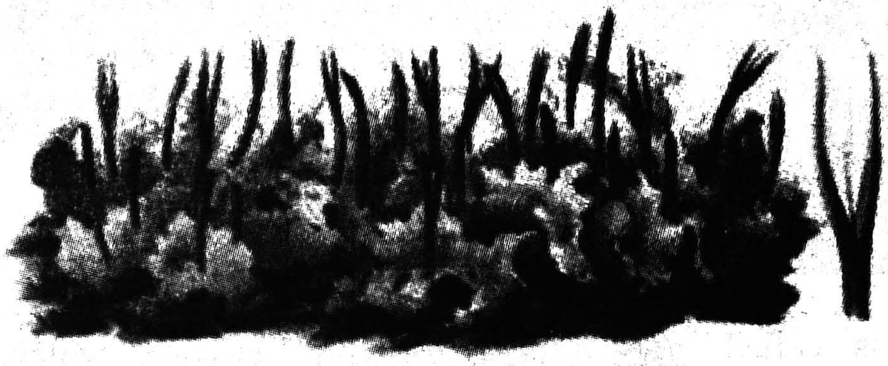

Capsule
Protonema
Spores
Buds
Meiosis
Gametophores
Sporophyte
Archegonia
Egg
Fertilization
Sperm
Antheridia

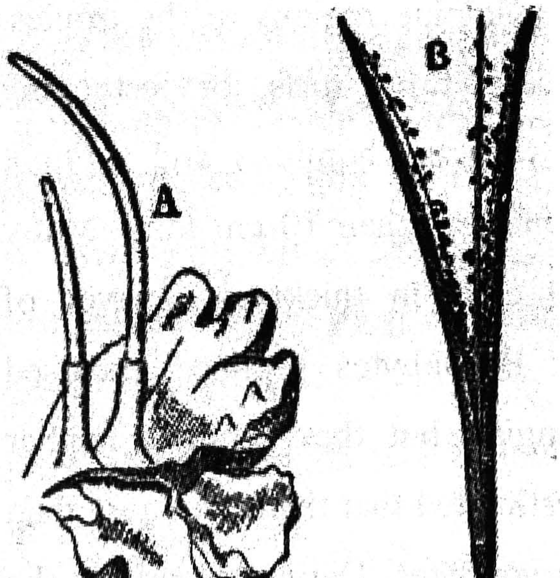

Sporophyte
Gametophyte

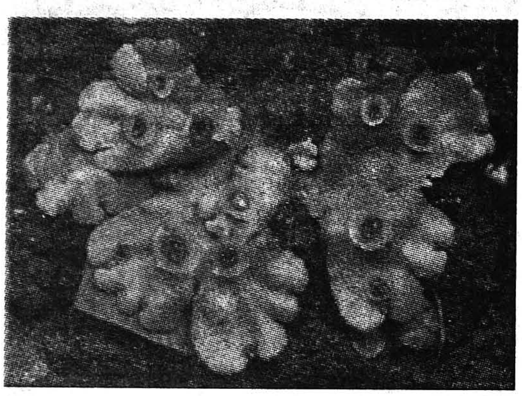


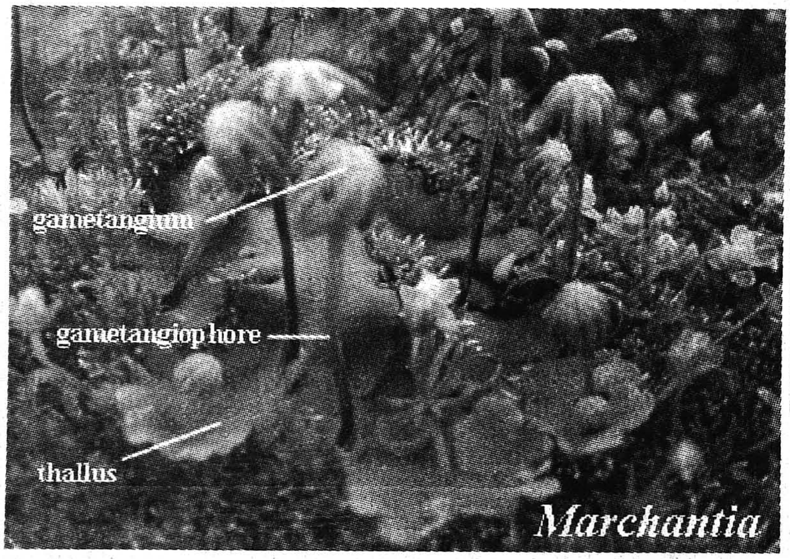

antheridia
500 µm
gametophyte tissue
Mnium antheridial head, c.s.


pore
air
epidermis
chloroplasts
Liverwort cross-section
rhizoid
soil




A
B





<u>Morphology</u>: Bryophyte is called '<u>non-vascular plants</u>'. They are widely distributed throughout the world, from polar and alpine regions to the tropics. Bryophytes form flattened mats, spongy carpets, tufts, turfs, or festooning pendants. These growth forms are correlated with the humidity and sunlight available in the habitat. Most are 2–5 cm tall and less than 10 cm long. Many mosses possess one or more midribs several cells in thickness. Leaves of liverworts are lobed. Mosses are unlobed. Bryophytes produce enclosed reproductive structures (gametangia and sporangia), but they produce neither <u>flowers</u> nor <u>seeds</u>, reproducing via <u>spores</u>. It is estimated that there are more than 1,000 genera and more than 18,000 species of bryophytes. Dating to early in the <u>Ordovician Period</u> (488 million to 444 million years ago), Bryophyta is the most ancient lineage of terrestrial plants.

Structure: Bryophytes are the simplest of the terrestrial seedless plants, lack complex xylem and phloem tissue organization. In bryophytes (mosses, liverworts and hornworts), the haploid gametophyte is the commonly known phase of the plant, on which the diploid sporophyte is dependent. An early developmental stage in the gametophyte of mosses (immediately following germination of the meiospore) is called the Protonema. The adult gametophyte of mosses is called the gametophore as it carries the gamete-producing sex organs. A **Gametophyte** is the haploid and multicellular. The gametophyte produces male or female gametes (or both), by a process of cell division called mitosis. The female and male gametes are also called, respectively, egg cells and sperm. The fusion of male and female gametes produces a diploid zygote, which develops by repeated mitotic cell divisions into a multicellular **Sporophyte.** Several spore capsules are produced underneath each umbrella of liverwort and the capsules hang downward, each held in place by a short seta. An immature sporophyte is enclosed within a protective sheath, which ruptures as the expanding sporophyte reached maturity. The mature sporophyte produces spores by a process called meiosis. The spores are therefore once again haploid and develop into haploid gametophytes.

Reproduction:

It is of two types:

(A) Vegetative Reproduction:

The gametophyte reproduces by fragmentation, by gemmae, by tubers, by protonema and by bulbils.

(i) Fragmentation of primary protonema:

Protonema formed by germination of spores is called primary protonema. In the protonema, some cells here and there die, due to which small fragments are produced. If a fragment of protonema has a bud of leafy gametophyte, it develops into an adult plant.

(ii) By secondary protonema:

From any portion of adult leafy plant, e.g. 'leaf, 'stem', 'rhizoid', some cells produce a protonema. This is called secondary protonema. Leafy buds arise here and their and are capable of giving rise to new adult plants.

(iii) By Bulbils:

Bulbils are resting buds produced on rhizoids or protonema. They get detached from the parent plant and under favourable conditions give rise to new plants.

(iv) By Gemma:

From the apical region of 'leaves' or axis, small gemma are produced which after being detached from parent give rise to new plant.

(v) Apospory:

Some cells from any part of sporophyte separate from the parent, fall on the soil and form a protonema. Buds of leafy gametophore are produced on protonema and give rise to a gametophyte like plant but the cells have diploid set of chromosome (2n). In this way, a gametophyte like plant is produced from sporophyte without reduction division.

(B) Sexual Reproduction:

Sexual reproduction is Oogamous. The biciliate antherozoids are borne in antheridia and oospheres (= eggs) are borne in archegonia, which are flask shaped structures differentiated into stalk, venter and neck. Water is essential for fertilization. Oospore (zygotes) is produced because of fusion of male and female gametes. Oospore gives rise to the sporophytic generations, called sporogonium. Sporogonium is completely (as in Riccia) or partially (as in Moss) dependent upon gametophyte. Sporophyte may be very simple and represented by a spore sac only as in Riccia or differentiated into foot, seta and capsule as in Moss. In the case of thallose liverwort (*Marchantia*) it is complex umbrella-like structure called **Gametophores**. Gametophores are two types:

Archegoniophore and Antherediophore. In the spore sacs, spore mother cells after reduction division give rise to haploid spores. All bryophytes are homosporous. Spores are very small, easily wind-dispersed, over long distances. Water is another dispersal agent and one group of mosses even attracts insects to

carry away the spores.The spores germinate to produce a **Protonema**, which later on develops into an adult gametophyte. All bryophytes show alternation of generation.

. The gametophyte produces the sex organs, the male or female sex organs, or both. The female sex organ is a flask-shaped structure called the archegonium. The archegonium contains a single egg enclosed in a swollen lower Venter portion. The neck of the archegonium is a single cell layer thick with the neck canal. When mature, the neck canal cells of the archegonium disintegrate, releasing a column of fluid to the neck canal and the surrounding water. The egg remains in the base of the archegonium, ready for fertilization. The male sex organ, the antheridium, is a saclike structure made up of a jacket of sterile cells one cell thick; it encloses many cells, each of which, when mature, produces one sperm. The antheridium is attached to the gametophyte by a slender stalk. When wet, the jacket of the mature antheridium ruptures to release the sperm into the water. Each sperm has two flagella and swims in a corkscrew pattern. When a sperm enters the field of the fluid diffused from the neck canal, it swims toward the site of greatest concentration of this fluid, therefore down the neck canal to the egg. Upon reaching the egg, the sperm burrows into its wall, and the egg nucleus unites with the sperm nucleus to produce the diploid zygote.

The zygote remains in the archegonium and undergoes many mitotic cell divisions to produce an embryonic Sporophyte. The lower cells of the archegonium also divide and produce a protective structure, called the calyptra that sheathes the growing embryo. As the sporophyte enlarges, it is dependent on the gametophore for water and minerals. The water and nutrients enter the developing sporophyte through the tissue at its base, or foot, which remains embedded in the gametophyte. Mature bryophytes have a single sporangium (spore-producing structure) on each sporophyte. The sporangium terminates an elongate stalk, or seta, when the sporangium is ready to shed its spores. The sporangium rupture involves specialized structures that enhance expulsion of the spores away from the parent gametophyte.

The bryophytes show an alternation of generations between the independent Gametophyte generation and the dependent Sporophyte generation. The gametophyte generation of the bryophyte is perennial and photosynthetically independent of the sporophyte. Gametophyte produces the sex organs, sperm and eggs. The dependent Sporophyte connects with the gametophytic tissue at the base with foot. In some bryophytes, Sporophytes are embedded within side the gametophyte tissue. Sporophyte produces the spores.

The life cycle of bryophytes consists of an alternation of two stages, or generations, called the Sporophyte generation and the Gametophyte generation. Each generation has a different physical form. When a spore germinates, it produces the Protonema, The protonema is threadlike highly branched in the mosses but is reduced to only a few cells in most liverworts and hornworts. Protonema organizes to develop more gametophyte plants.

Classification; Modern Bryologists classify Bryophyta into the following three classes, namely, Hepaticopsida, Anthocerotopsida and Bryopsida.

Bryophyta

Hepaticopsida (Hepaticae) Liverworts Orders: 1. Takakiales 2. Calobryale 3. Jungermanniales 4. Metzgeriales 5. Marchantiales 6. Sphaerocarpales 7. Monocleales	**Anthocerotopsida** (Anthocerotae) Hornworts Order: 1. Anthocerotales	**Bryopsida** (Musci) Mosses Subclasses: 1. Sphagnidae 2. Andreaeidae 3. Buxbaumidae 4. Bryidae 5. Polytrichadae

The above-mentioned system of classification has beeen adopted by Takhtajan (1953), Schuster (1953), Parihar (1965) and Udar (1976).

Characteristic features of Hepaticopsida:

1. The plant body thalloid or foliose
2. Rhizoids without septa; simple and tuberculate, ventral scales present
3. Cells have chloroplast without pyrenoids
4. Sex organs develop from supereficial cells on the dorsal side of the thallus
5. Simple Sporophyte
6. Columella absent, elaters maybe present
7. Sporophyte completely dependent upon the gametophyte for nutrition
8. Dehiscence of sporangium is irregular or regular

Characteristic features of Anthocerotopsida:

1. The plant body is thalloid and dorsiventrally flattened
2. Simple rhizoids without septa, scales absent
3. No tissue differentiation
4. Sex organs embedded in the thallus
5. Elongated Sporogonium, araise from the dorsal side of the thallus
6. Capsule wall has chlorophyll and stomata
7. Columella and pseudo-elaters are present

Characteristic features of Bryopsida:

1. The adult gametophyte consists of 'stem', spirally arranged 'leaves' and the sex organs at its tipapical portion
2. Multicellular branched rhizoids with oblique septa
3. Sporophyte differentiated into foot, seta and capsule
4. Capsule wall has stomata
5. Elaters are absent

Ecological significance

Extensive carpets of Bryophytes on soil help in moisture conservation and flood control. During sudden downpours of rain, numerous species can quickly absorb (and retain) many times their dry weight in water. The absorbed water is then gradually released over a longer period, reducing the erosive effects of heavy rain and allowing other plants to benefit for a longer period from the rain. In arid

areas, extensive carpets of Lichens, Bryophytes and Cyanobacteria play important ecological roles. Such cryptogam carpets are called BIOLOGICAL SOIL CRUSTS. Such a crust slows down the flow of water and soaks into the underlying soil.

Some species are very effective sand and soil binders and can help in erosion control. In arid areas, bryophytes associate with lichens, create extensive crusts on the soil and help to maintain the underlying soil structure.

Bryophyte colonies provide niches for numerous invertebrates, which are then eaten by larger invertebrates, which, in turn, are eaten by other creatures. Such bryophyte colonies are thus indirectly important in various food chains.

Some aquatic bryophytes participate in rock formation by absorbing minerals dissolved in the water. When dead, the plants sink to the bottom and so deposit the absorbed minerals. Bryophytes are also good at trapping nutrients from the air. These nutrients become available to other organisms. Living bryophytes make use of the nutrients they trap and dead, decaying bryophytes release nutrients to the surrounding plants. In these ways, bryophytes play an important role in nutrient recycling.

Bryophyte mats are ideal nurseries for all vascular plant seeds. Bryophyte mats provide ideal sites for the germination of vascular plant seeds. In moister forests, it is common to see orchids, ferns and other vascular plants growing from moss-covered tree trunks. Mat can provide a stable microhabitat, protected against the drying effects of sun and wind and the extremes of temperature. Therefore, a seed that falls into a carpet find successful germination. Moreover, a seed is protected against many seed-eating insects, birds and mammals.

Some Crustose lichens are very effective at keeping bryophytes away, with chemical defenses. Lichens produce a wide variety of chemical compounds, some have negative effects on bryophytes - acting to prevent spore germination or inhibiting protonemal or gametophytic growth.There is a small number of lichens, *Nostoc* and *Oscillatoria* that are soft and gelatinous in winter, but dry to a hard crust in summer. When these are found growing amongst bryophytes the dry, crusty states easily, kill the embedded bryophytes by suffocation.

Many animals make use of bryophytes. Numerous invertebrates eat bryophytes, lay their eggs on them or shelter in them. They form a vital part of the construction material of the nest of some birds. Frogs are found near *Sphagnum* bogs. These endangered frogs breed in *Sphagnum* bogs in the alpine and sub-alpine areas. Mosses have a low nutritional value and are ignored by the larger animals. Some arctic Reindeer eat moss. These mosses contain high levels of arachidonic acid, which helps cells to keep working at low temperatures and supplying to the animals with a natural antifreeze compound.

Bryophytes also absorb a wide variety of potentially toxic compounds. Some pollutants inhibit spore germination and protonemal growth, but less effect on a gametophyte. Pollutants come in many forms from both urban and rural areas. Smelters produce heavy metal pollutants, cars produce nitrogen oxides and nuclear reactors produce radioactive pollutants. sulfur dioxide are readily absorbed through bryophyte thalli, once absorbed, disrupt photosynthesis. Some bryophytes are highly tolerant of sulfur dioxide pollution and examples of these are the mosses *Funaria hygrometrica* and *Bryum argenteum*. The moss *Polytrichum formosum* to the nitrogen dioxide concentrations found alongside rural British roads, growth was first stimulated but later there were significant reductions in old shoots and in new shoot formation.

Wildfires are common in many parts of the world. The effects on Bryophytes are also varied. A rapid fire has no effect on bryophyte. The bryophyte colonies on logs suffer a little damage. By contrast a slow, hot fire burn bryophytes and logs to charcoal. Ash increases the alkalinity of the ground. *Funaria hygrometrica* is an early coloniser of burnt areas. *Marchantia* gametophytes appear within a few weeks after a fire

In wetlands such as bog lands and swamps, Bryophytes absorb great quantities of water and release organic acids, which decrease decomposition rates. This accumulation of biomass over thousands of years forms ecosystems such as the Okeefenokee Swamp, the bogs in Canada, Northern US and across the oceans.

Economic importance

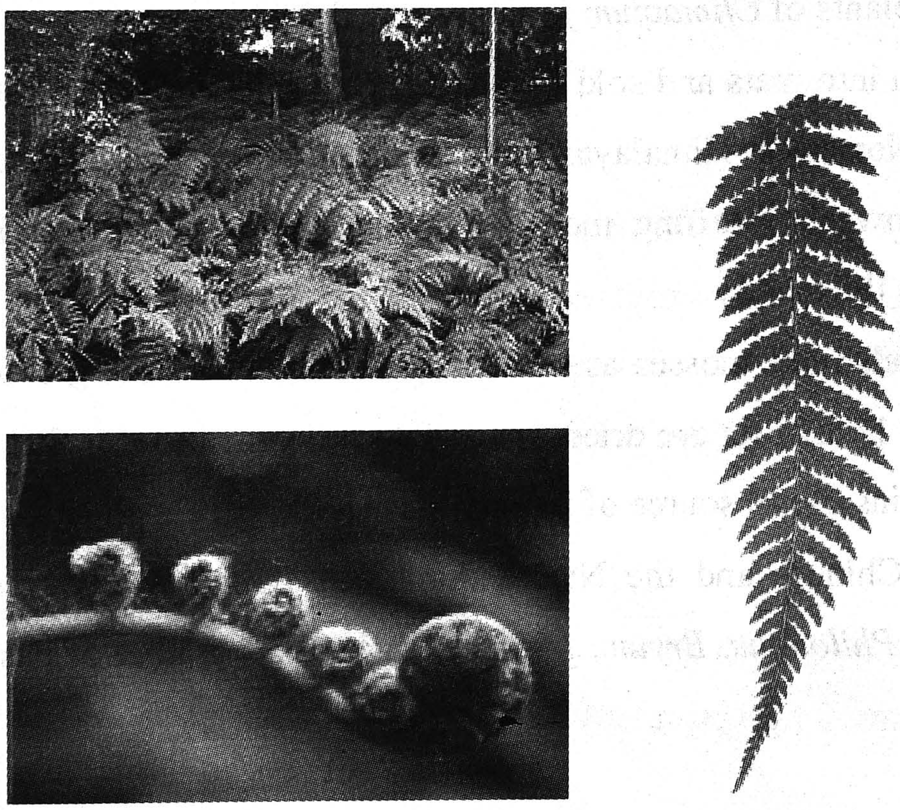
- **Wrapping and wall paper** was made from *Sphagnum* in the early 1900's
- More recently, S*phagnum* are used for making **construction material**: Peatcrete, a mixture of *Sphagnum*, Portland cement and water;
- Commonly used in **mixtures of soil** to loosen compact soils and increase water-holding capacity.
- Because of its absorbent and **antiseptic properties** it was used for dressings during World War I, to make pillows for resting of wounded members for soldiers transported to hospitals from battlefields, and recently as filling material for sanitary napkins.
- In Japan, mosses are traditionally used as base **cover for bonsai,** in **miniature landscapes** and in the designs of the famous **Japanese gardens.**
- In **folk medicine,** particularly in China, 40 species are used in various remedies. Mosses are used to treat cardiovascular, nervous problem, skin rashes, burns, infections and bites. The moss *Rhodobryum giganteum* contains volatile oils, **lactones and amino acids,** increases **rate of blood flow** in the aorta
- Accumulated dried beds of Peat moss *Sphagnum* are used as a **fossil fuel.** In the scotch industry, this peaty fuel gives 'peaty' taste to the scotches.
- Bryophytes are used in a variety of industrial applications. Different species of mosses are used as furniture stuffing, as soil conditioner, as cushioning, and as material used to absorb oil after spills.
- Most economically important bryophyte is Peat moss *Sphagnum.* It has specialized hyaline cells to store water. So it is used as **storage material** and also as **absorbent.**
- *Polytrichum juniperinum* is tall moss that holds soil in place, looks like a small tree in a garden, and is strong enough to make brooms, baskets, and door mats.

- Bryophytes show great promise for cleaning up toxic waste. Peat mosses (*Sphagnum*) are even more suitable than other kinds of mosses for cleaning up toxic waste.
- Peat has been considered a possible material for filtering water for reuse in space travel.
- Decorative horticultural uses include flowerpots and containers for floral arrangements.
- Nurserymen use wet *Sphagnum* for shipping live plants.
- Mosses accumulate minerals such as potassium, magnesium, and calcium from rainfall. These trapped nutrients are released slowly from mosses to soil. When mosses become dry, their cell membranes suffer damage, repair this damage with accumulated nutrients.
- Villagers of Himalayas use moss mats with shrubs, grasses, and bamboo to make a pharki, a kind of door placed at the openings of their temporary huts.
- Mosses are used for Household Uses: decorative purposes in Japan, England, France, Finland and America. Ornamental water flowers are made from dried plants of *Climacium japonicum* and sold.
- Mosses are woven into mats and sold in many parts of India. In the alpine highlands of the Northwest Himalayas, Indians make bedding, mattresses, cushions and pillows by stuffing mosses into coarse linen sacks or by spreading them on the muddy
- The Himalayans also use mosses as insect repellents when storing food. Local mosses and liverworts are dried, made into a coarse powder that is sprinkled over grains useful source of insecticides and insect repellents.
- Medicinal Uses: Chinese and the Native Americans have used various moss species like *Philonotis, Bryum, Mnium*, crushed into a kind of paste and applied.

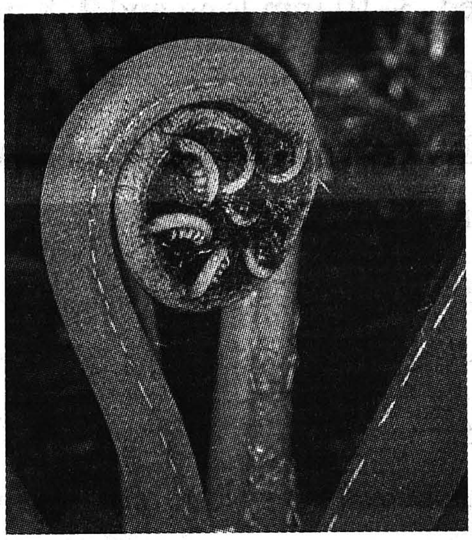
- In India, the burned ash of mosses mixed with fat and honey is used as an ointment for cuts, burns and wounds. The liverwort *Marchantia polymorpha* is also used as medicine for boils

Pteridology: General account: Morphology, structure and reproduction. Classification of Pteridophytes; Stelar evolution; Heterospory and orgin of seed habit. General account of fossil Pteridophytes; Salient features of Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

General account: *Pteridology* is the study of ferns—plants classified in the **Division Pterophyta** (or Filicophyta). Ferns do not have seeds. They have spores like mosses. The haploid spores grow into small haploid gametophyte called Prothallus. Then undergo fertilization and grow into diploid sporophyte called fern plant. Fern plant emerge out directly from the Prothallus. Ferns have roots, which, unlike moss rhizoids, not only anchor, but also take up nutrients. Ferns are vascular plants, with lignified vascular tissues. These allow active water transport. One difference between sporophytes and gametophytes is"Nothing eats ferns, but everything eats gametophytes."



Ferns at the Royal Melbourne Botanical Gardens



Structure:

- Stems: An underground creeping rhizome, but sometimes an above-ground creeping stolon (e.g., Polypodiaceae), or an above-ground erect semi-woody trunk (e.g., Cyatheaceae)
- Leaf: The green, photosynthetic part of the plant is a megaphyll and in ferns, it is referred to as a frond. New leaves expand by the unrolling of a tight spiral called a crozier or fiddlehead. This uncurling of the leaf is termed circinate vernation. Leaves are divided into three types:

Trophophyll: A vegetative leaf that does not produce spores, instead only producing sugars by photosynthesis.

Sporophyll: A fertile leaf that produces spores borne in sporangia that are clustered to form sori. Roots: The underground non-photosynthetic structures that take up water and nutrients from soil. They are always fibrous and are structurally very similar to the roots of seed plants.

The Gametophytes of ferns, however, are very different from those of seed plants. They consist of:

- Prothallus: A green, photosynthetic structure that is one cell thick, heart or kidney shaped, 3–10 mm long and 2–8 mm broad. The prothallus produces gametes by means of:
    - Antheridia: Small spherical structures that produce flagellate sperm.
    - Archegonia: A flask-shaped structure that produces a single egg at the bottom, reached by the sperm by swimming down the neck.
- Rhizoids: root-like structures (not true roots) that consist of single greatly elongated cells, water and mineral salts are absorbed over the whole structure. Rhizoids anchor the prothallus to the soil.
- **Reproducution:**
- **Sporangia (Clustered in sori)**
- The sporangia are the structure, which produces spores. In ferns, the sporangia are aggregated into particular bigger structures called **Cluster Sori**.
- **Spores;** spore is the product of meiosis.
- **Spore germination:** Spores are released into the wind. Land and grow into a gametophyte. It is just like a little, thin, small green plate. It will produce the sex cells, the eggs and the sperm.
- **Gametophyte (prothallus)**
- The prothallus is the fern gametophyte. The prothallus has both male and female sex organs.

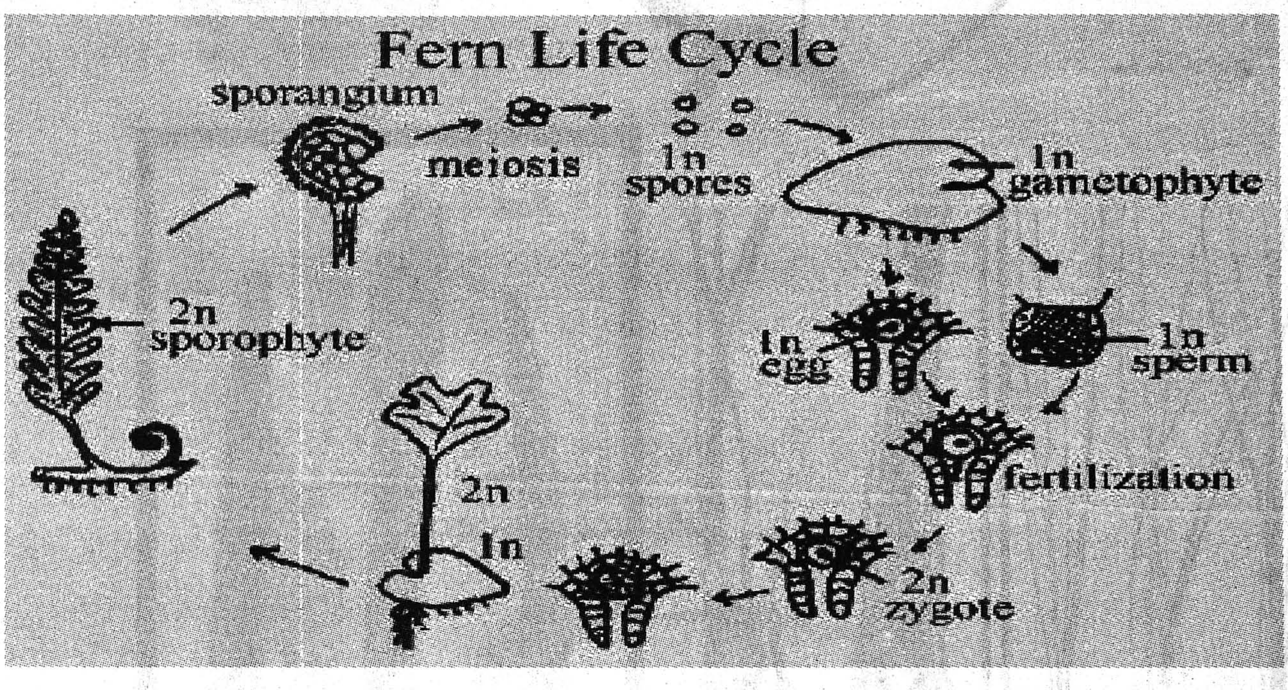
Antheridium: The antheridium is the male sex organ. These small spherical structures produce flagellate sperm.

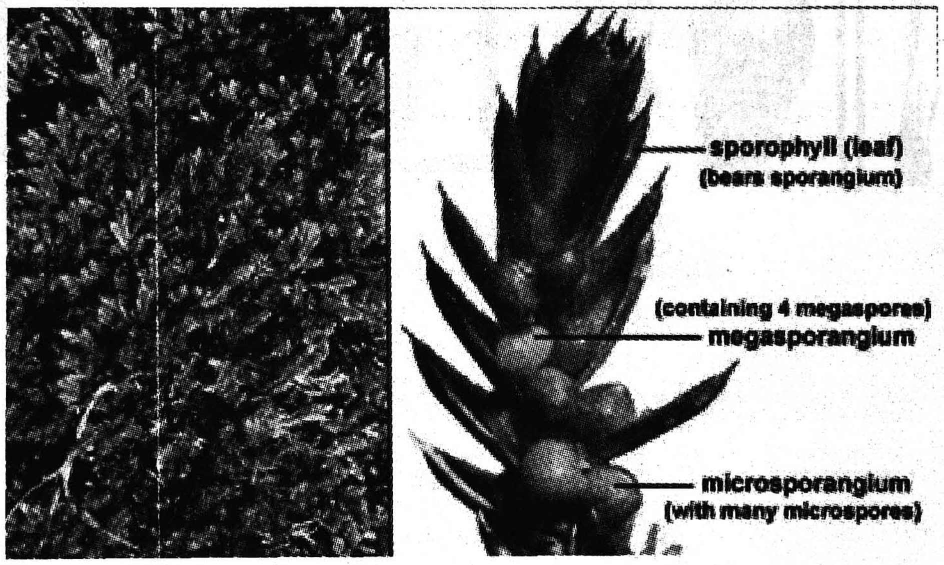
Archegonium: The archegonium is the female sex organ. These are flask-shaped structures that produce an egg.

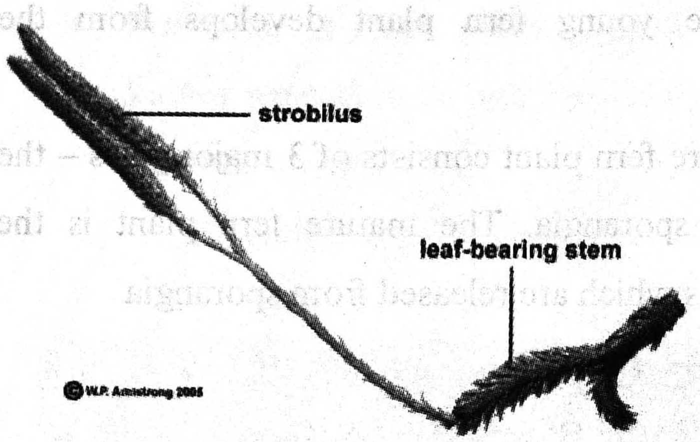
Fertilisation: The sperm swim through water to the eggs. Fertilisation occurs. The sperm and egg come together. That doubles the number of chromosomes, that gives rise to a completely new typical fern plant again, and the cycle repeats.

- **Developing sporophyte;** The young fern plant develops from the prothallus.

  Mature sporophyte; The mature fern plant consists of 3 major parts – the rhizome, the fronds and the sporangia. The mature fern plant is the sporophyte that produces spores which are released from sporangia






strobilus
leaf-bearing stem
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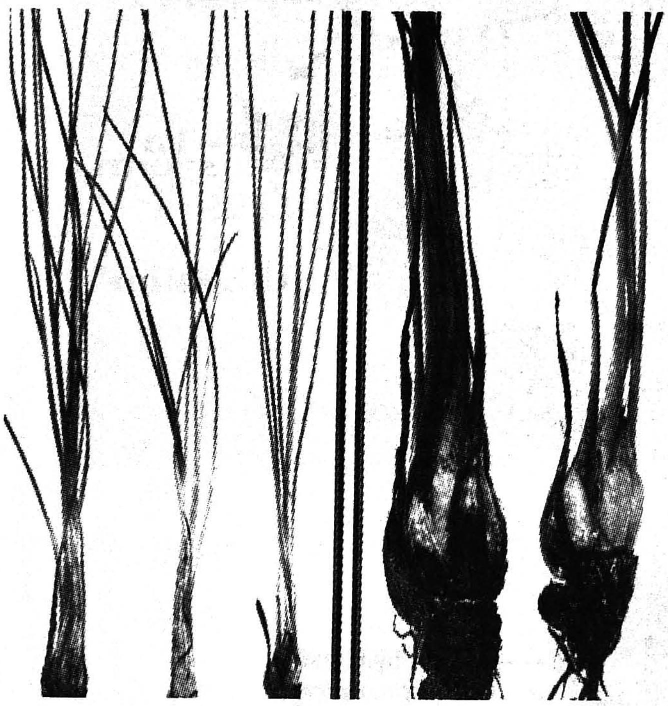

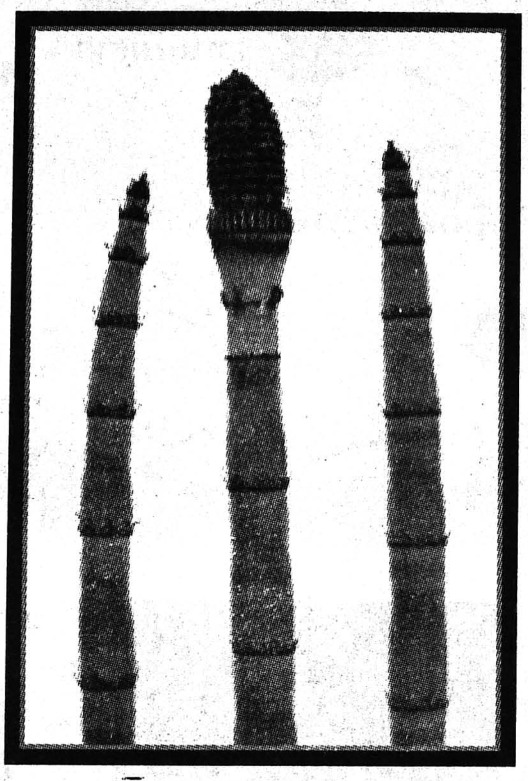

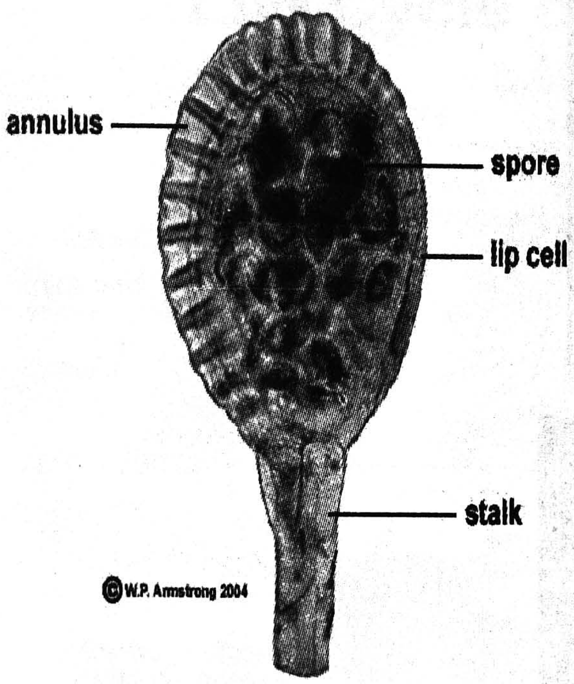
annulus
spore
lip cell
stalk
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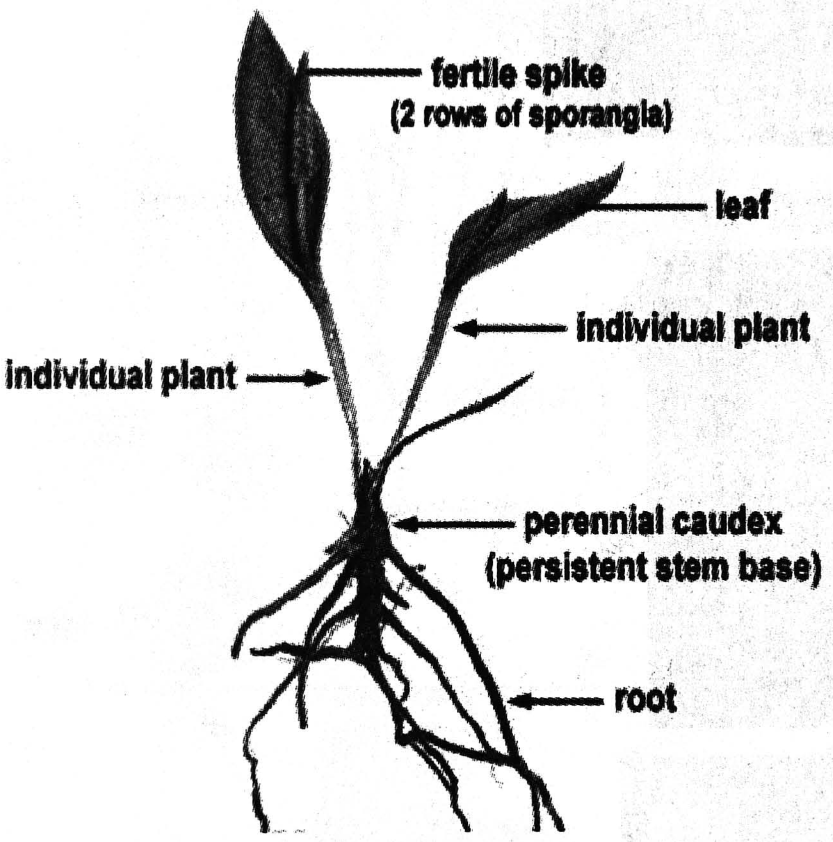
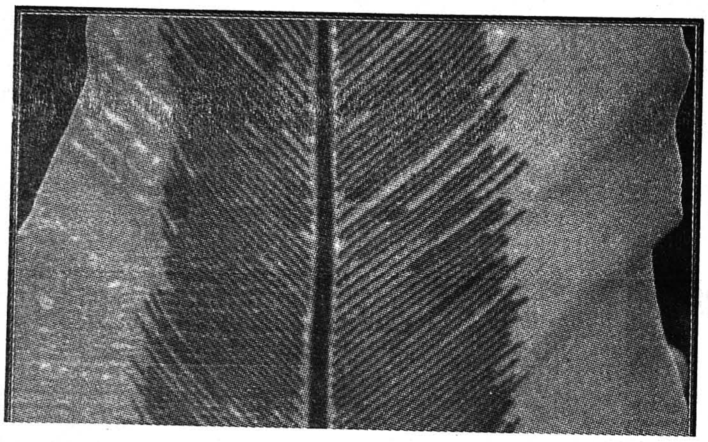
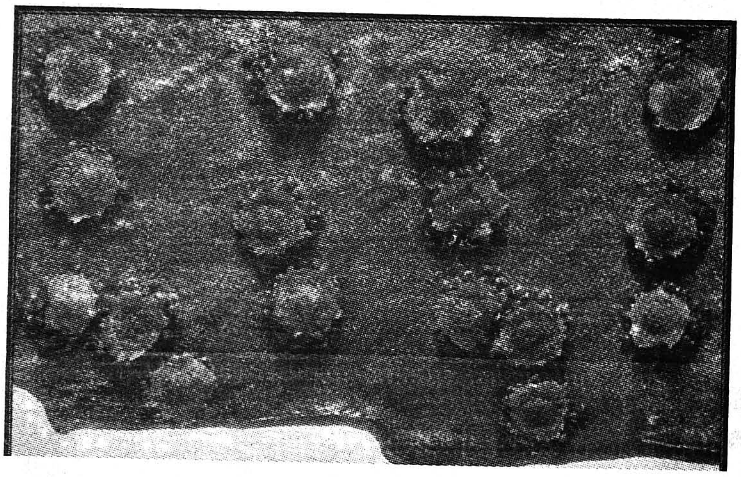
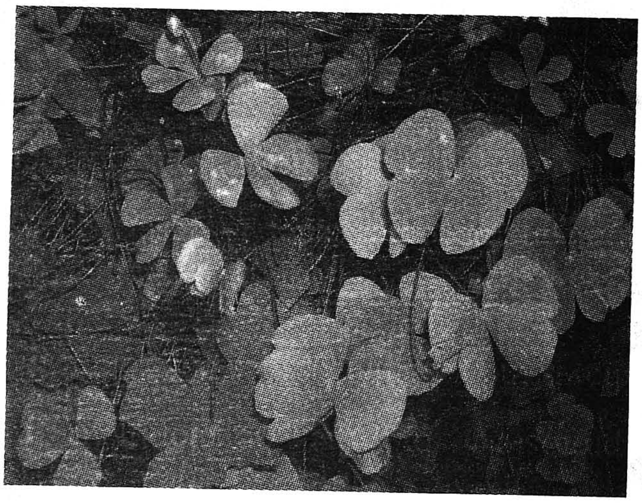
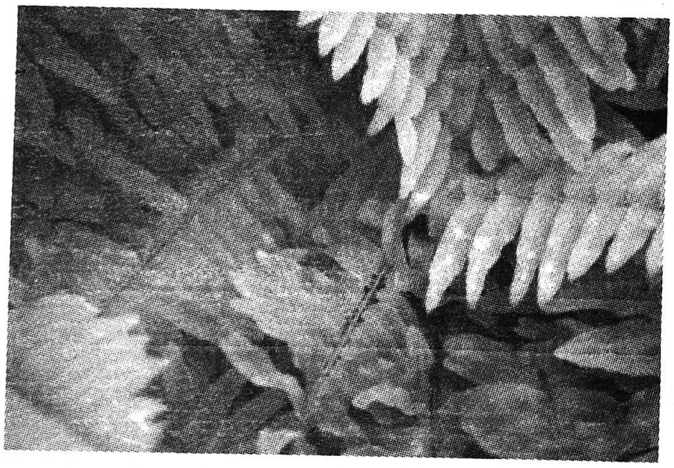

fertile spike
(2 rows of sporangia)
leaf
individual plant
individual plant
perennial caudex
(persistent stem base)
root

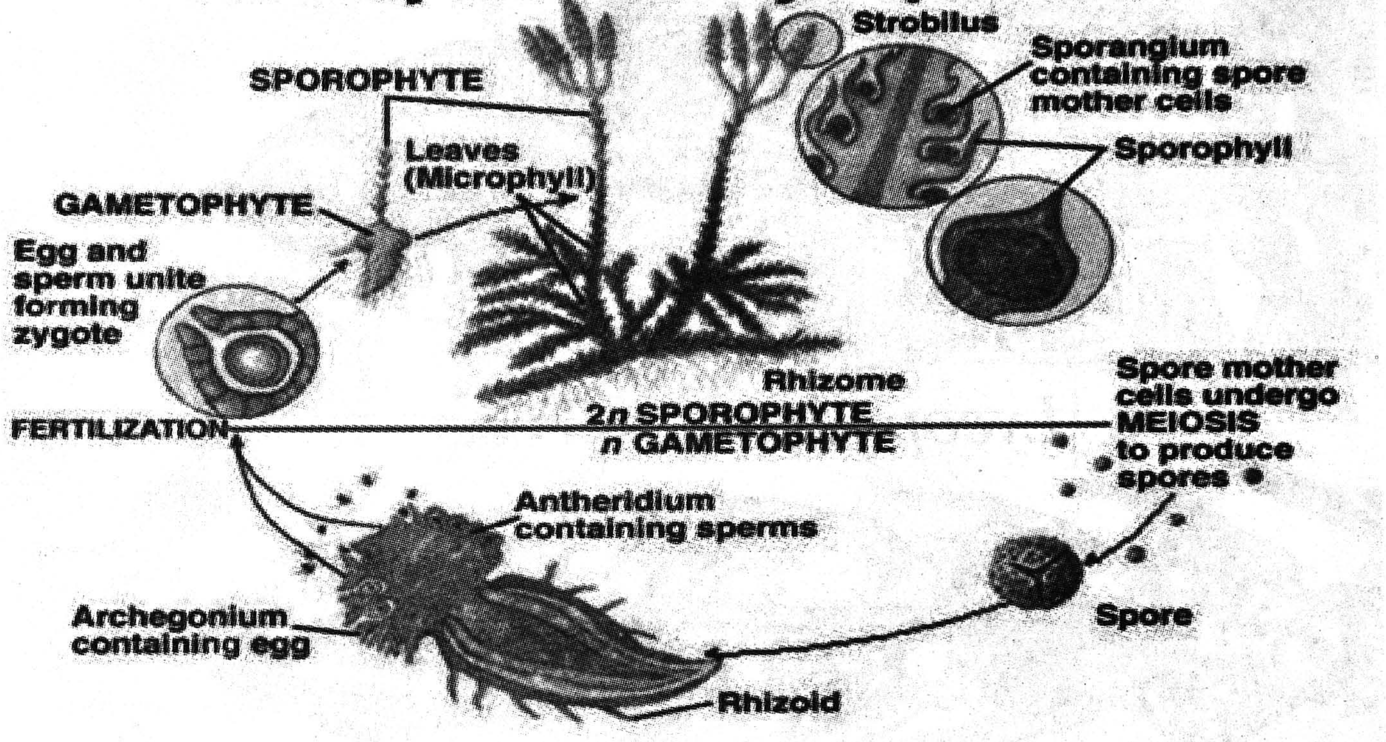


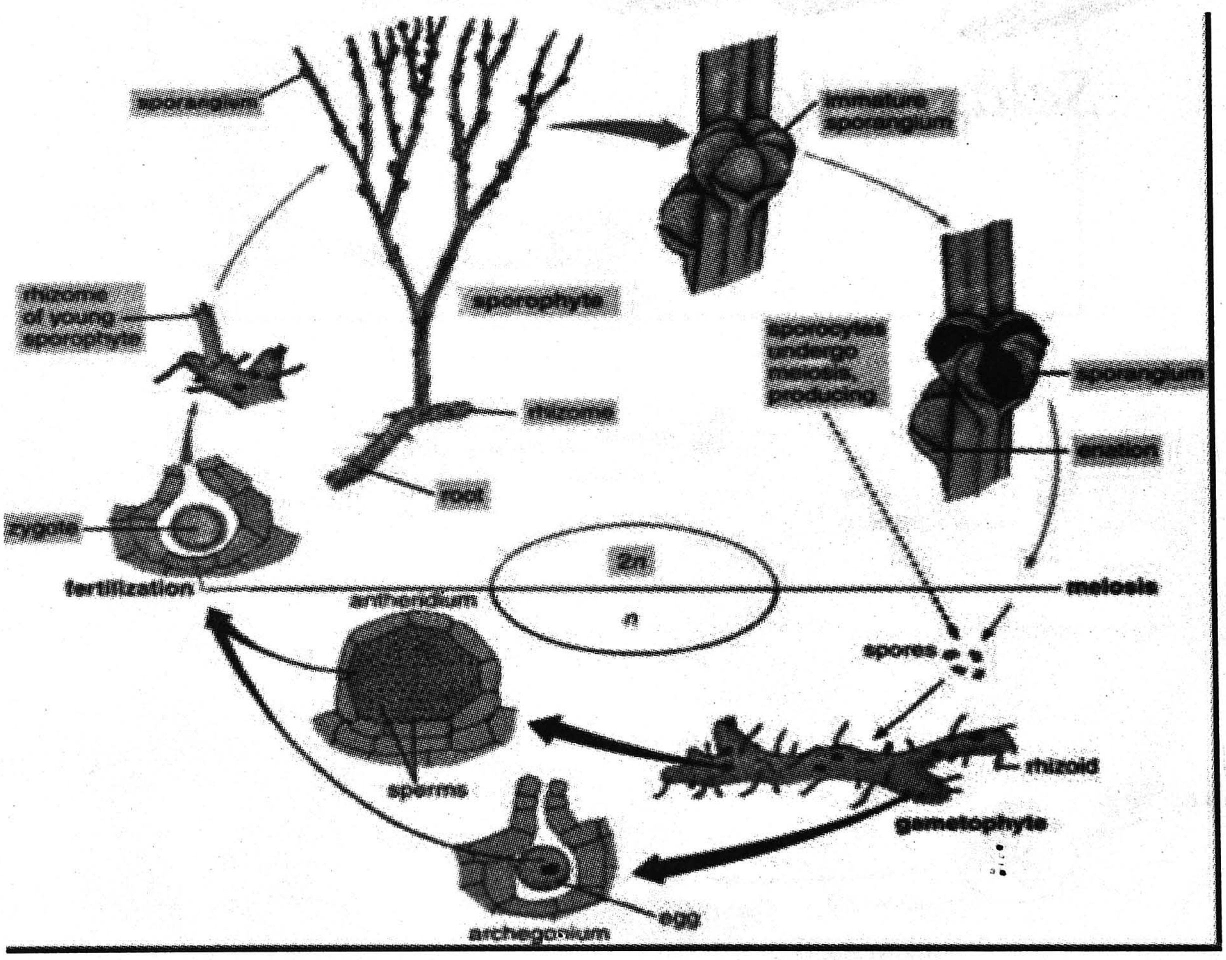


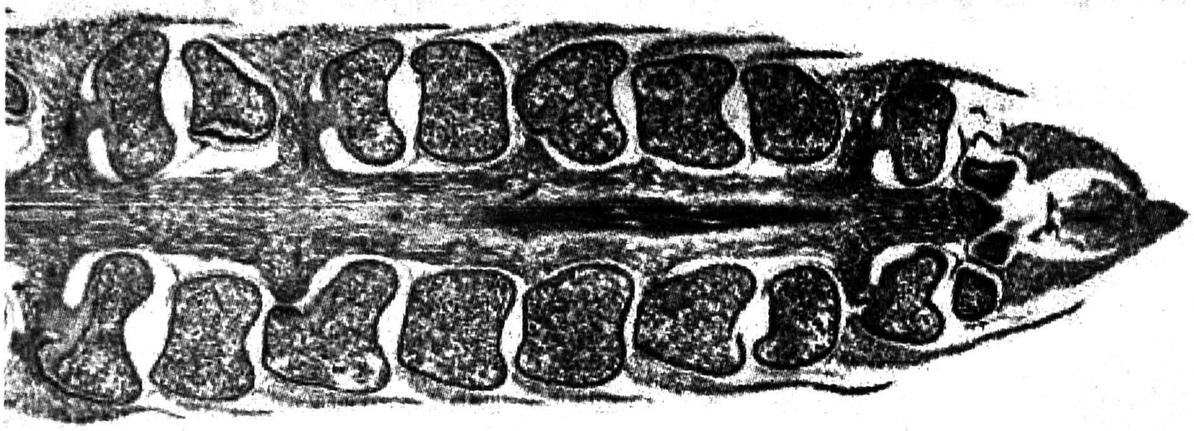




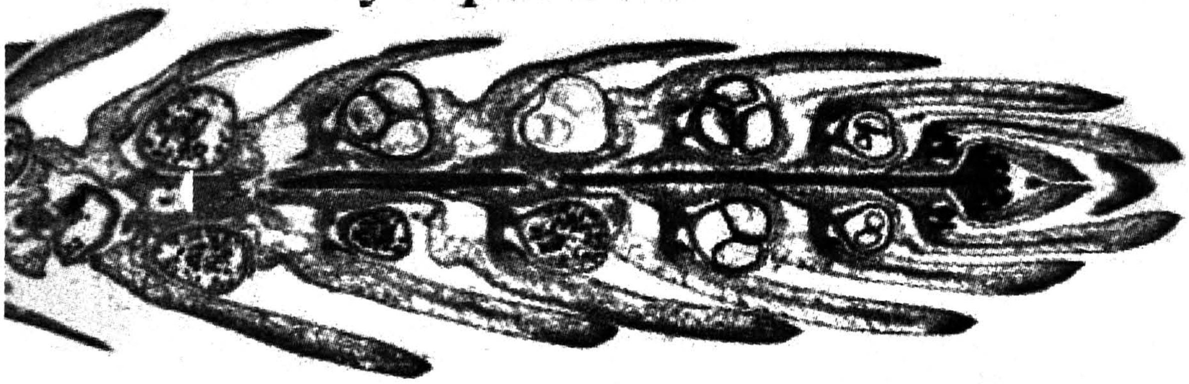
Life Cycle of a *Lycopodium*



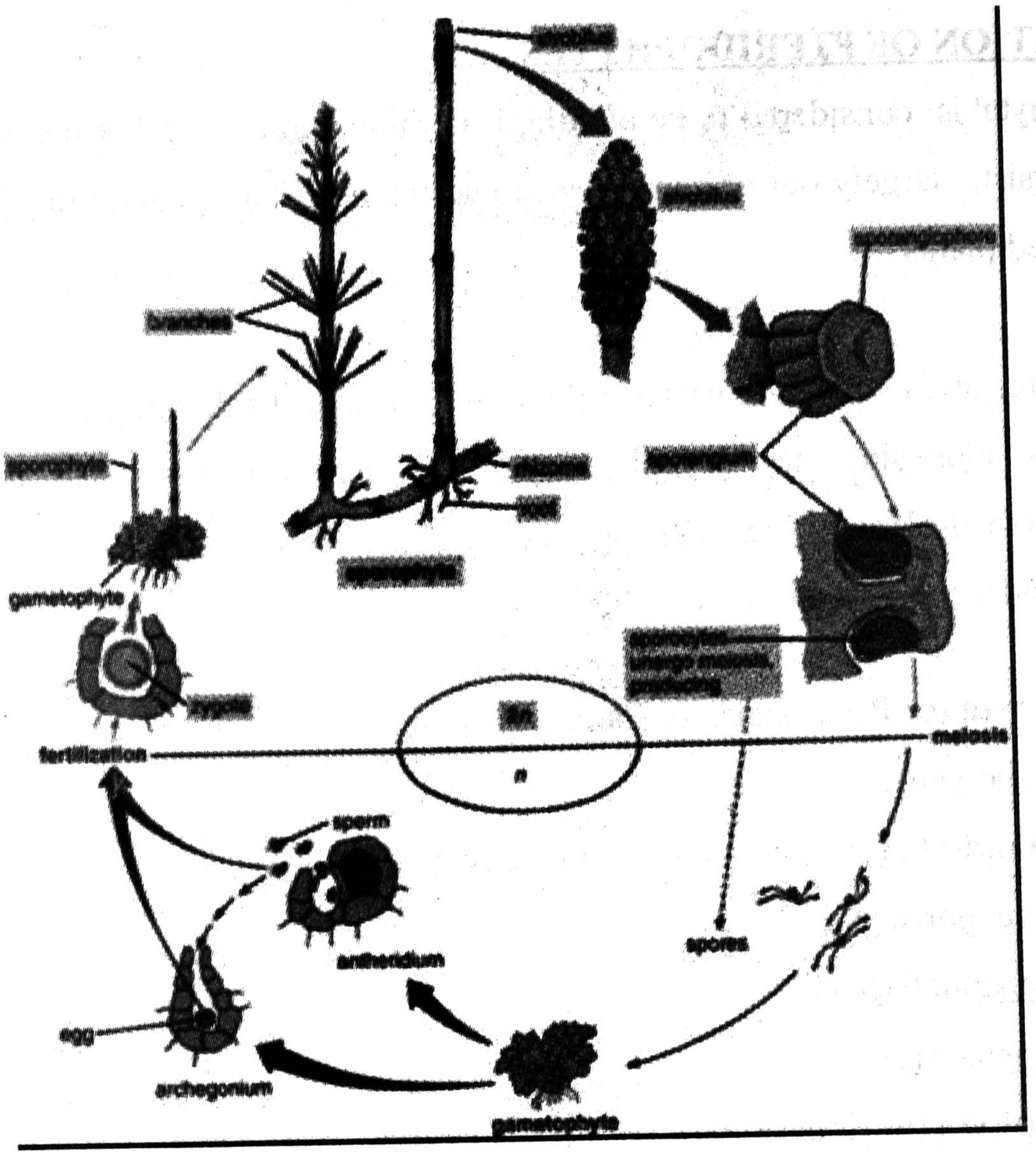


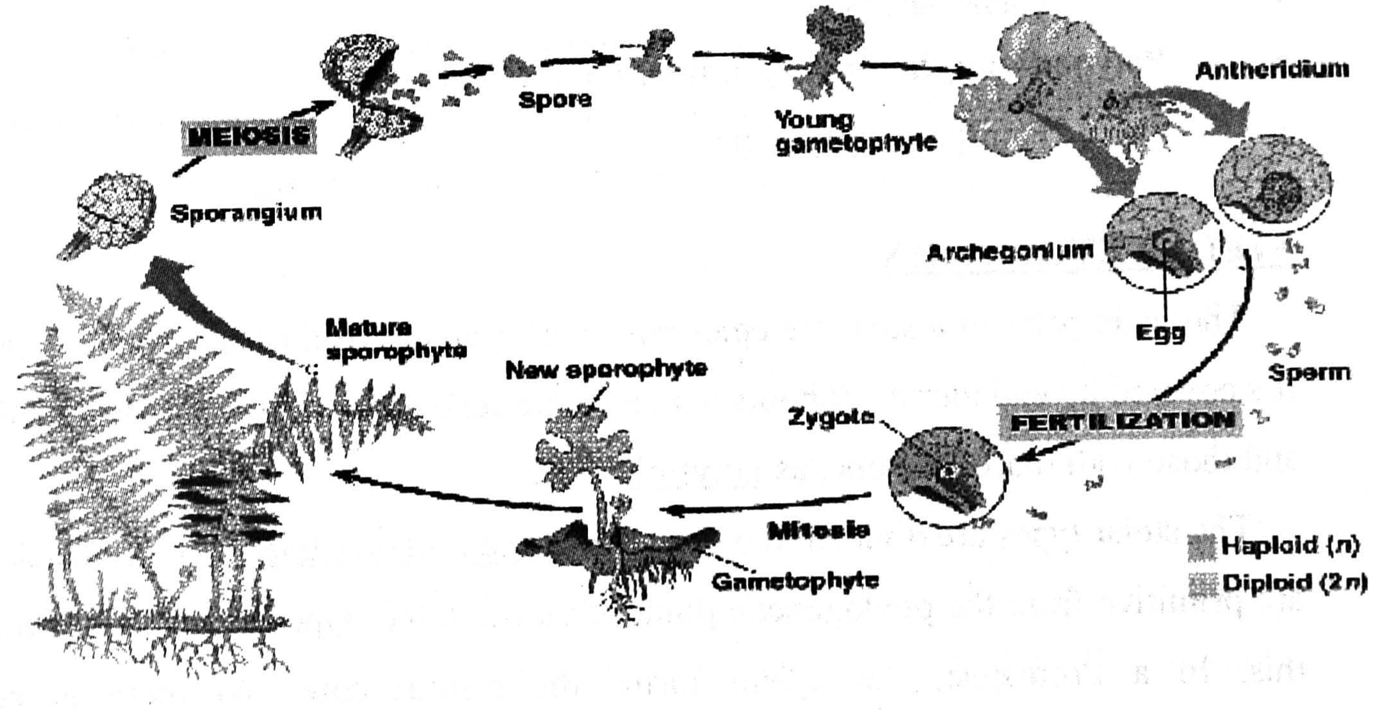


Lycopodium



Selaginella


gametophyte
zygote
fertilization
meiosis
n
sperm
antheridium
spores
egg
archegonium
gametophyte


MEIOSIS
Spore
Young gametophyte
Antheridium
Sporangium
Archegonium
Egg
Sperm
Mature sporophyte
New sporophyte
Zygote
FERTILIZATION
Mitosis
Gametophyte
Haploid (n)
Diploid (2n)

CLASSIFICATION OF PTERIDOPHYTES

The 'Pteridophyta' is considered to be a biologically unnatural group but the use of the term persists, largely out of convenience and the need for a handle for the 'ferns and related plants'.

The pteridophytes are a collection of several major groups at the division or class level that rank alongside the Bryophyta (mosses and liverworts) and the Spermatophyta (seed-plants). There are four such groups, one of which is the true ferns, the remainder the fern allies:

- **Psilotophyta** (or Psilotopsida or **Psilopsida**)
  - Psilotaceae
- **Lycopodiophyta** (or Lycopodiopsida or **Lycopsida**)
  - Lycopodiaceae
  - Selaginellaceae
  - Isoetaceae)
- **Equisetophyta** (or Equisetopsida or **Sphenopsida**)
  - Equisetaceae)
- **Polypodiophyta** (or Polypodiopsida or **Filicopsida**)
  - Families of true ferns

STELAR EVOLUTION

The main parts of a stem are epidermis, cortex and central hard core, the stele. It s covered by endodermis. Shoots with a single stele are described as Monostelic and those with more than one, as Polystelic.

The stelar types are divided into Protosteles and Siphonosteles. The protosteles are primitive from the phylogenetic point of view... Other types are evolved from this. In a Protostele, the xylem forms the central core and there is no parenchymatous pith at the centre.

However, Siphonostele shows pith at the centre and the vascular tissues form around the pith.

Protostele: It consists of a central core of xylem surrounded by phloem and pericycle.Many simple Pteridophytes have protosteles. The protostele is described as a haplostele if the central xylem mass is like a smooth cylinder (*Rhynia*) or xylem has radiating ribs, known as actinostele (*Lycopodium serratum*) . Actinostele is more advanced than haplostele. In L. phlegmaria, the actinostele shows several armss calaled polyarch. An advanced type of protostele is found in the *L. volubile*, an actinostele is broken into separate lobed plates, xylem lie parallel to one another called Plectostele. Thus, xylem and phloem occur in alternate bands. In more advanced forms, the xylem is loosely scattered as strands in the groundmass of phloem. This is described as mixed haplostele e.g., *L.cernuum.*

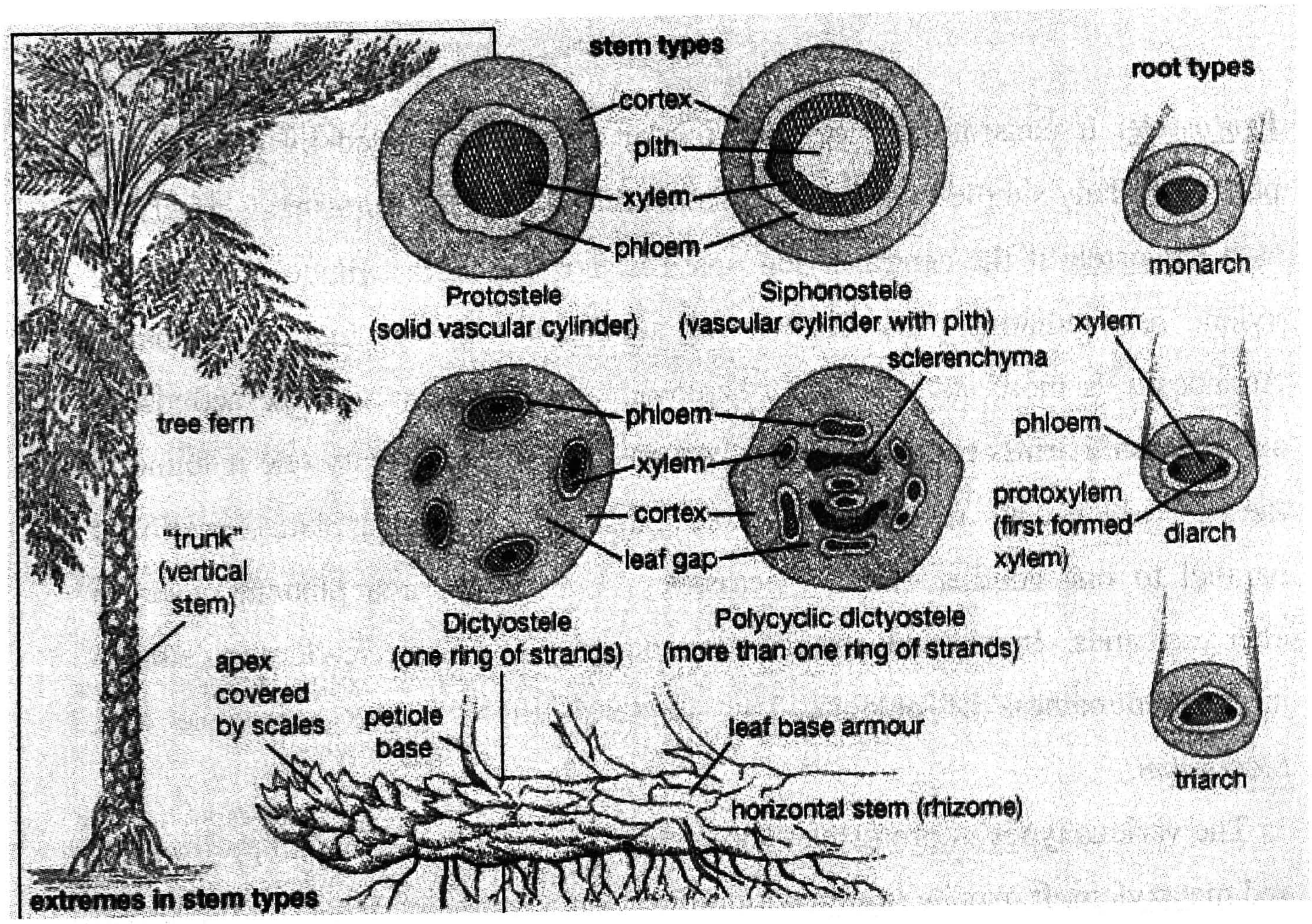
The various types of protosteles show variations in the positions of protoxylem and metaxylem. It may be exarch with protoxylem near the periphery of the xylem strands, or may be endarch with the protoxylem at the inner surface. In the mesarch condition, metaxylem is present both towards the outer and inner sides of protoxylem. The endarch conditon is considered to be the most evolved and exarch condition is primitive in our concept of stelar evolution.

Siphonostele: is derived from the protostele by the development of parenchymatous medulla. A siphonostele shows the vascular tissues encircling the pith.

The xylemis surrounded by phloem only on the outer side, is described as ectophloic siphonostele. If phloem is present on the uter side as well as theinner side, it is described as amphiphloic siphonostele (*Marsilea*).

In the simplest cases, siphonostele shows no leaf gap as in *Selaginella sp*. In proimitive members, the leaf gaps are at a distance and so they do not overlap. Such a siphonostele without overlapping leaf gaps is a solenostele. Siphonostele with overlapping leaf gaps is known as dictyostele or dissected siphonostele.

Polycyclic stele: Most advanced conditon. In this, separate steles are arranged in rings within one another.



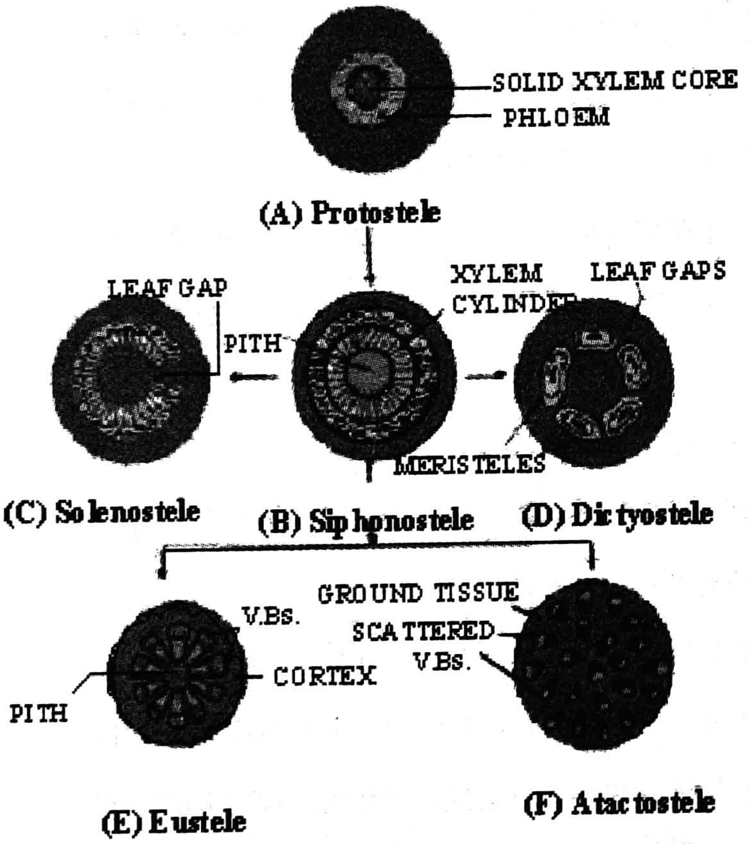
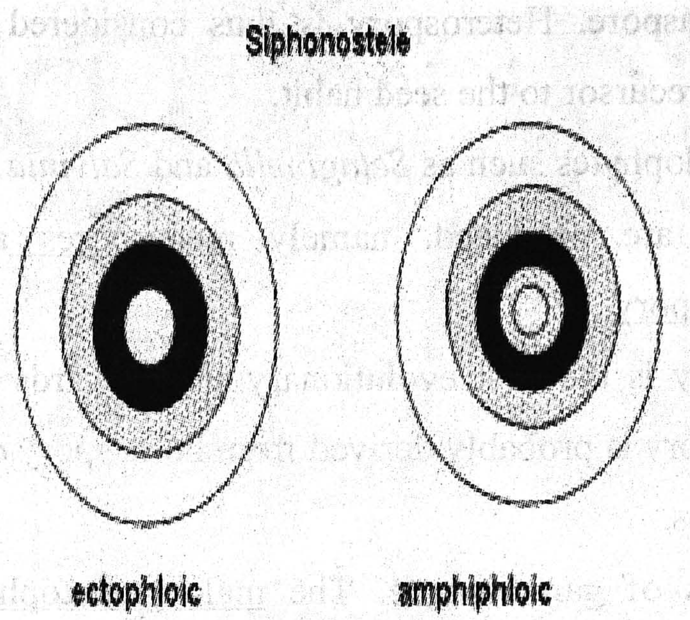


Figure 15.25 Main types of Stele (all diagrammatic)



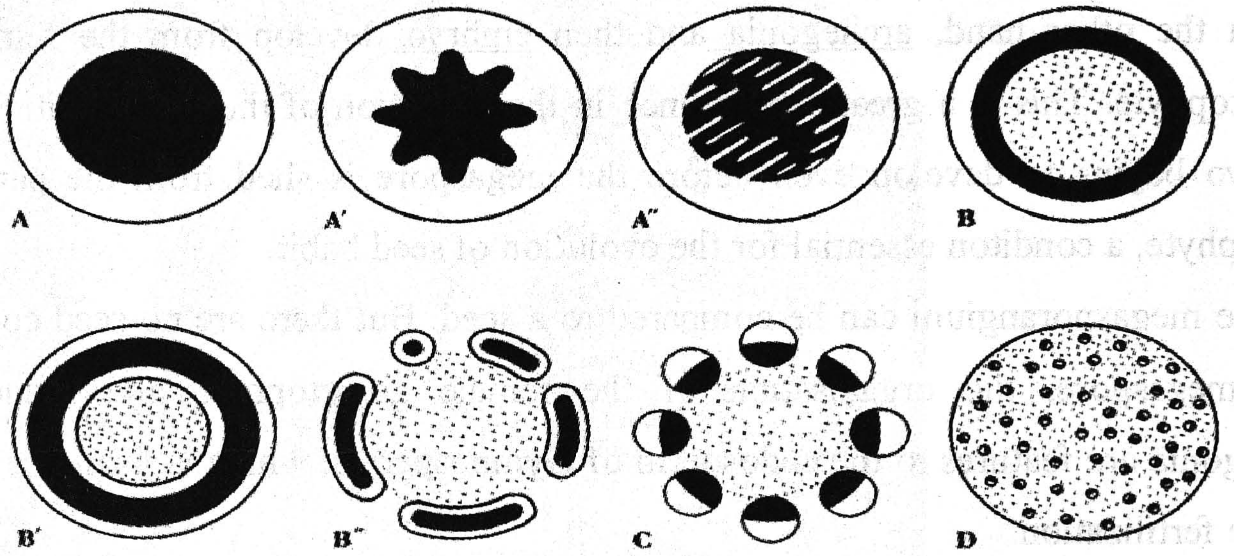


FIGURE 13-6
Types of stele, diagrammatic transections. A–A''. Protosteles. A. Haplostele. A'. Actinostele. A''. Plectostele. B. Ectophloic siphonostele. B'. Amphiphloic siphonostele or solenostele. B''. Dictyostele. C. Eustele. D. Atactostele. Xylem, black; phloem, white; pith, stippled.

HETEROSPORY AND ORGIN OF SEED HABIT

Heterospory is a phenomenon in which two kinds of spores are borne by the same plant. These spores differ in size. The smaller one is known as microspore and the larger one is known as megaspore. The microspore germinates to form the male gametophyte and the megaspore germinates to form the female gametophyte. The male gametophyte releases the male gametes and these reach the female gametophyte to fuse with the egg. The development of the zygote takes place inside the female gametophyte. This retention and germination of the megaspore within the megasporangium ensures proper development of the zygote. The zygote develops into the future sporophyte. The evolution of the seed habit is

related to the retention of the megaspore. Heterospory is thus considered an important step in evolution as it is a precursor to the seed habit.

Heterospory evolved first in pteridophytes such as *Selaginella* and *Salvinia.* In *Selaginella,* two kinds of spores are produced, namely megaspores and microspores. This is known as heterospory.

Bower considered that heterospory is the first evolutionary step towards the establishment of seed habit. Heterospory is probably derived from homospory due to changes in the nutritive relationships.

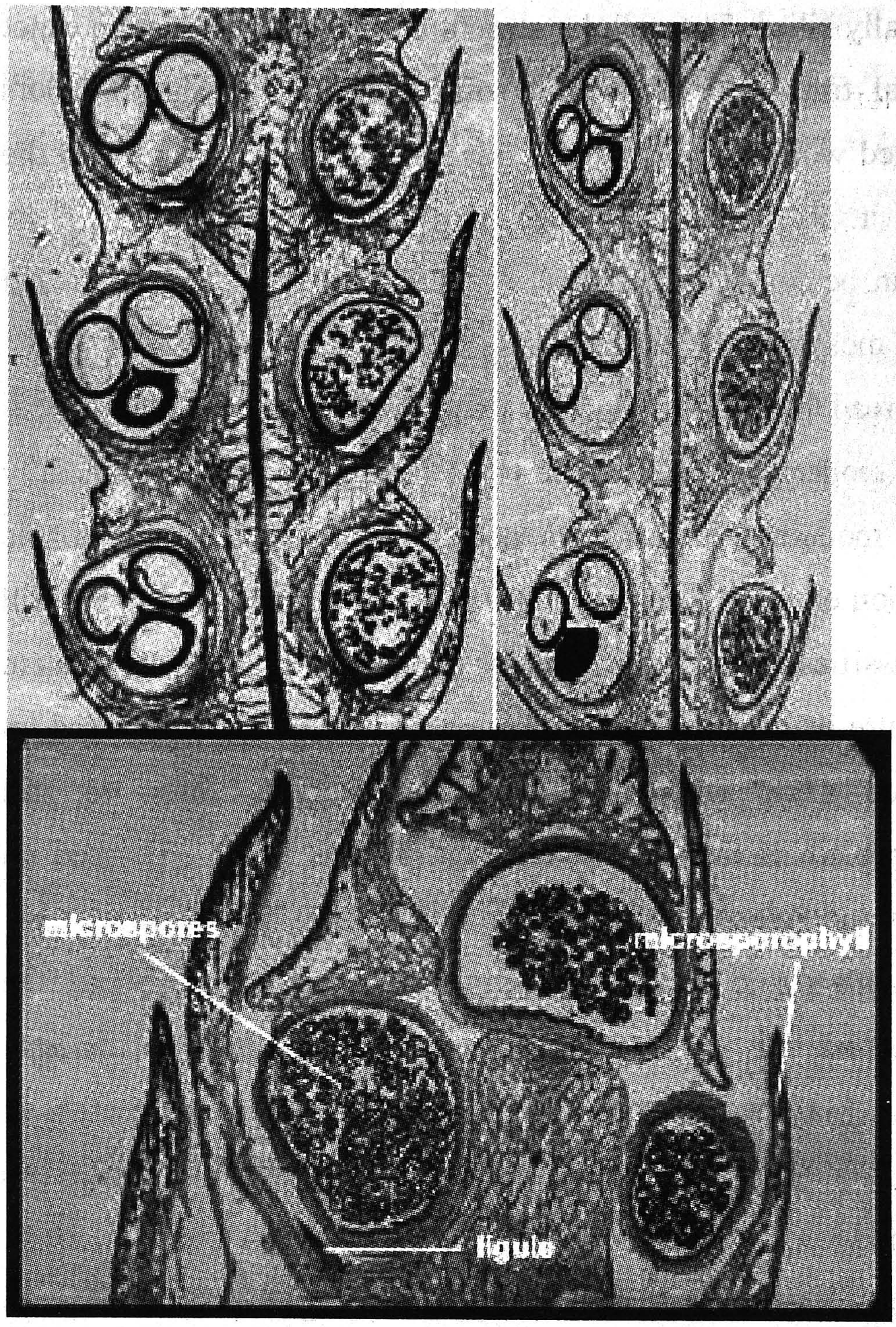
Heterospory results in two types of gametophyte. The male gametophyte develops from the microspore and the female gametophyte from macrospore.

On the other hand, archegonia and then embryo develop from the female gametophyte. This is a great significance in the evolution of the seed habit. The embryo begins to develop even before the megaspore is shed from the parent sporophyte, a conditon essential for the evolution of seed habit.

The megasporangium can be compared to a seed. But there are no seed coats. The megaspore, the organisation of the female gametophyte and reduced archegonia are features to the endosperm of Gymnosperms, which is formed even before fertilization.

In *Selaginella*, the sporangium breaks open and the spore coat cracks open to expose the female gametophyte. This is very essential for exposing the archegonia, so that fertilization may take place. The spermatozoids directly enter the archegonia. But in Gymnosperms, the female gametophyte is never exposed; the plllen grains germinate at a distance and the pollen tube carries the sperms or male cells to the egg.

Thus, the retention of a thick spore coat, megaspor remaining free in the megasporangium, absence of nucellus, exposing the archegonia by the break up of sporangial wall the spore coat, entry of biciliate spermatozoids directly into the archegonia at the time of fertilization and absence of integuments and micropyle are all features still primitive in *Selaginella*.



GENERAL ACCOUNT OF FOSSIL PTERIDOPHYTES

Plants were the earliest known life on Earth, arising billions of years ago. Plants are also currently the oldest living organisms on Earth. Fossil plants are some of the most widely recognized fossils ever found. Coal, amber, petrified wood, and some forms of crude oil are all unique forms of fossilized plant material. Even the air we breathe is a result of millions of years of oxygen production by the Earth's plant kingdom. We owe it all to them. Petrified Wood is a very well known fossil plant. Under certain conditions, entire trees, even entire forests, can become fossilized. In the petrification process, the solid trunk of a tree is replaced cell by

cell by a mineral, usually silica. The cellular structure of the tree is then an exact replica of the original tree, only it is now solid rock. The beautiful colors associated with petrified wood come from the trace elements associated with the mineral that replaced it. Red, yellow, orange, and green are examples of the vibrant colors than can be found in petrified wood. Colorful pieces of petrified wood are probably the most displayed type of fossil plant available.

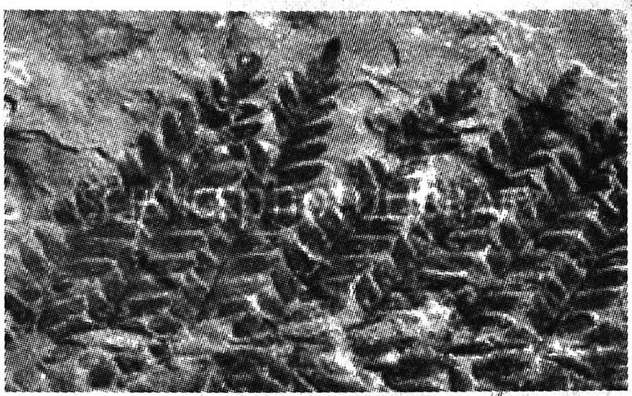
Ferns were widespread in the Carboniferous and Permian. Many had a tree-like growth habit like modern tropical tree ferns. However, though superficially looking very similar, modern tree ferns are not directly related to Palaeozoic forms. The classification of fossil ferns is very difficult and many aspects are still uncleared. Several classification schemes have been published. A major problem is the fragmentary nature of the material. Some groups are exclusively based on anatomically preserved axes, whereas foliage and fructifications are still unknown. Another problem is that the systematics of ferns is largely based on modern representatives and Palaeozoic forms do not fit well.

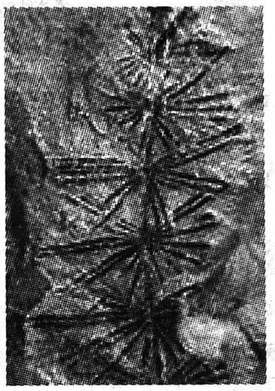
Most groups of Palaeozoic ferns are extinct. The Marattiales and the Osmundales are the oldest still existing fern groups and date back to the Late Carboniferous Permian Majority of extant ferns belongs to groups that have evolved in the Mesozoic. The Polypodiaceae, the most successful fern group today, is even much younger and dates from the Late Cretaceous Tertiary.

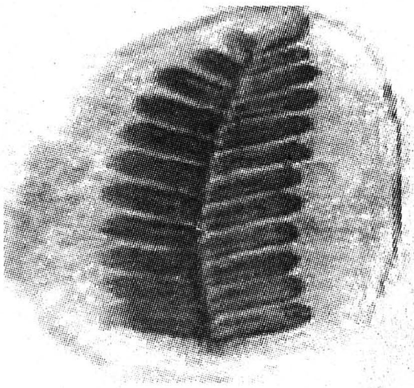
Palaeozoic ferns had various growth strategies ranging from tree-like, to winding, climbing and epiphytic forms. North American Stephanian coals consist of up to 75% of tree fern remains.

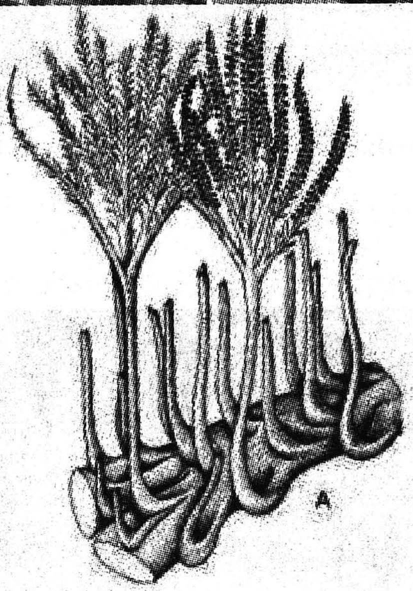
Fossilized tree bark is also very interesting. Early trees usually had very distinct bark patterns - diamond-shaped, scale-shaped, etc. Occasionally, branches or trunks of these trees fell to the forest floor and became fossilized. These logs left their unique bark pattern imprinted forever in the rock. Some of these bark sections are many feet long; others are hand-sized remains. However, many of these ancient bark patterns are both striking and beautiful.

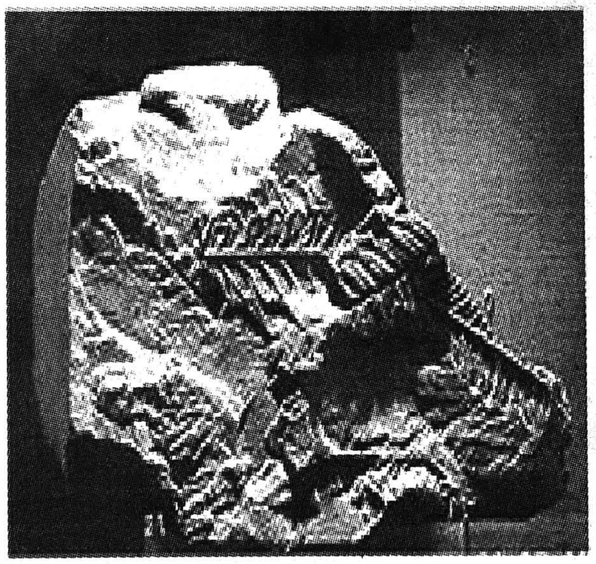
Flowers are very rarely found as fossils. They were extremely delicate in nature and only bloomed a few weeks each year. Some flower fossils have their petals and stamens intact, and some even have the original color pattern preserved.

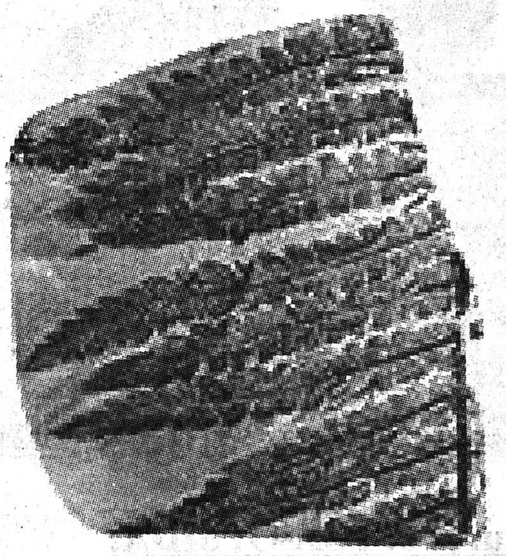


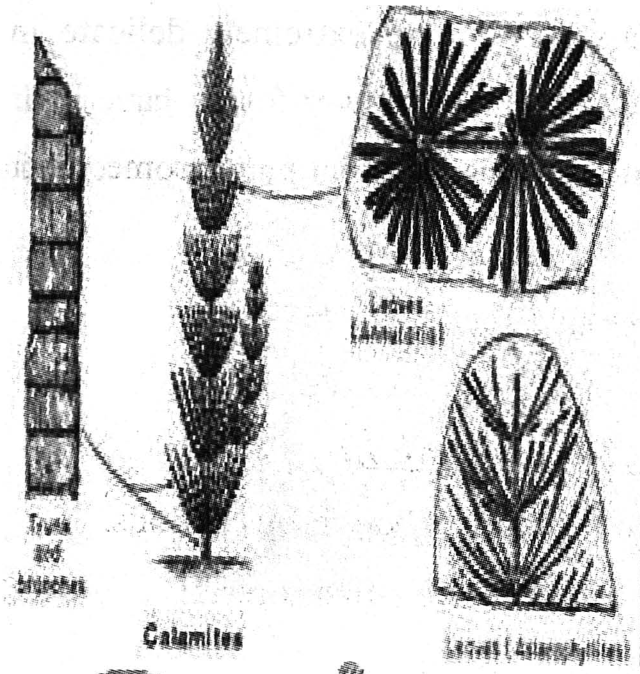


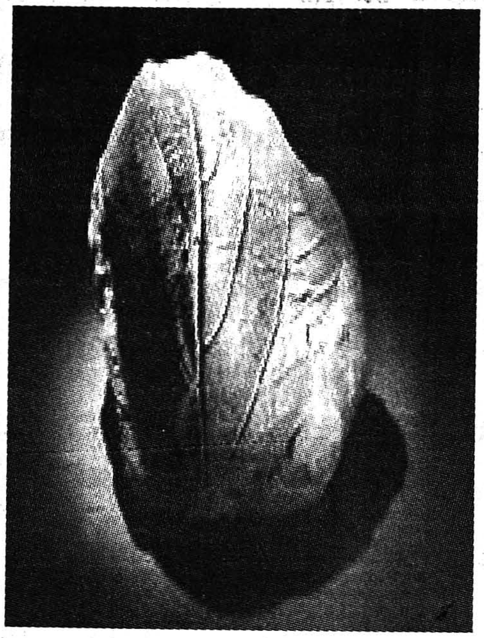


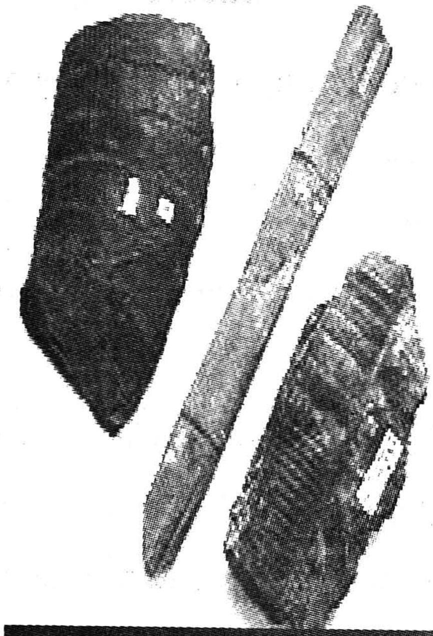


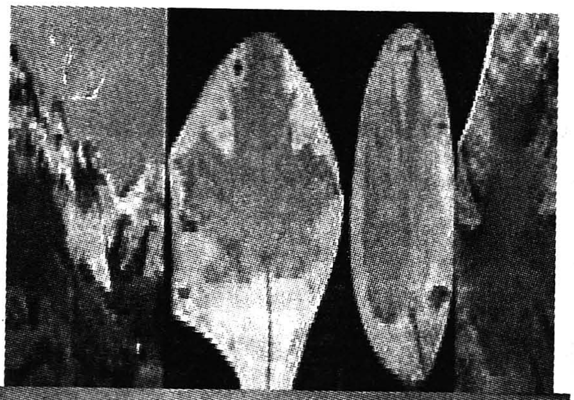


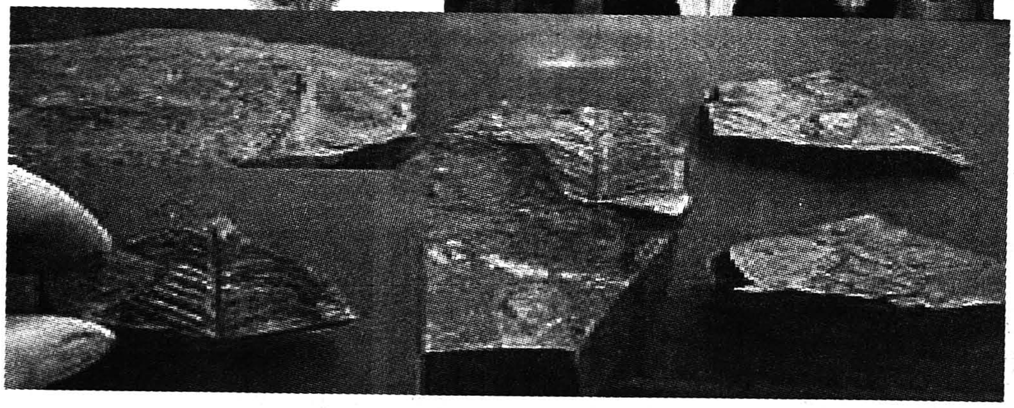












1.Salient features of PSILOPSIDA:

- These are the fossil representatives of the vascular plants, belonging to "Silurain period" and "Devonian Period"
- Sporophytes are simple dichotomously branching plants.
- True leaves and true roots absent.
- Underground stems that contain unicellular rhizoid similar to root hairs.

- The aerial stems are green and carry out photosynthesis.
- Lacking secondary growth due to absence of "Cambium"
- Reproductive structure "Sporangia" develop at the tips of some of the aerial branches.
- Meiosis produces haploid spores, within the sporangia.
- E.g. *Rhynia, Psilotum*

2.*Salient features of LYCOPSIDA(THE CLUB MOSSES):*

- These plants belong to middle Devonian and carboniferous periods.
- They were very large trees that formed the earth's first forests.
- Only five living genera of this group are present.
- Two members, *Selaginella* and *Lycopodium* are common in many areas of India
- These plants have true-branched underground roots.
- True leaves also present. They have arisen as simple scale like outgrowth from the outer tissues of the stem.
- Specialized reproductive leaves bearing sporangia on their surfaces, are present, such type of leaves are known as "Sporophylls".
- In some members, the sporophylls are collected on a short length of stem and form cone like structure "Strobilus".
- The cone is club-shaped; hence name "Club-Mosses" for the Lycopsids.
- Gametophytes plant are homosporous or heterosporous .

A) HOMOSPOROUS GAMETOPHYTES

- Spores produced by sporophyte plant are all alike, and each give rise to a gametophytes that bear both archegonia (female reproductive structure) and antheridia (male reproductive structure)
- Example *Lycopodium* (Running pine or ground pine)

B) HETEROSPOROUS GAMETOPHYTES

- Sporophyte (2n) plant produces two types of sporangia, which produced different kinds of spores.
- One type of sporangium produces very large spores called "Megaspores," which develop in female gametophytes bearing archegonia.
- Other type of sporangium produces small spores called "Microspores", which develop into male gametophytes bearing antheridia.
- That mean sexes are separate in the gametophytes generation (Heterosporous).

3. SPHENOPSIDA (THE HORSE TAILS):

- These plants belong to late Devonian and Carboniferous period.
- Only one living member "*Equisetum*" commonly called "Horse-tail" exists today.
- Ancient sphenopsids were large trees but now most of these are small (Less than one meter).
- Coal deposits of today were formed from the dead bodies of those plants.
- These plants possess true roots, stems and leaves.
- Stems are hollow and are jointed, whorls of leaves occur at each joint.
- Secondary growth absent, because modern species do not possess cambium.
- Spore are born in terminal cones (Strobili) and all are alike (i.e. plants are homosporous) and give rise to small gametophytes that bear both archegonia and antheridia (i.e. the sexes are not separate).

4. PTEROPSIDA (THE FERNS)

- These plants belong to Devonian and Carboneferous Period and then decline in Paleozoid Period.
- They are very well developed plants having vascular system with true roots, stem and leaves.
- Leaves are probably arisen from flattened web branched stems. They are large and provide much greater surface area for photosynthesis.

- Leaves of Ferns are sometimes simple, but more often they are compound, being divided into numerous leaflets.
- In most modern ferns of temperate regions, the stems are prostrate on or in the soil, and the large leaves are only part normally seen.

SPOROPHYTIC STAGE

- The large leafy plant (fern) is diploid sporophytic phase.
- Spores are produced in sporangia (Reproductive structure) located in clusters on the underside of some modified leaves "Sporophyll."
- Most modern ferns are homosporous i.e. all these spores are alike.
- Vascular sporophytes can live in drier places and grow bigger.

GAMETOPHYTE STAGE

- After germination, the spores develop into gametophytes that bear both archegonia and antheridia.
- These gametophytes are tiny (less than one centimeter wide), thin and often more or less heart-shaped.
- Free-living, non-vascularized gametophytes can survive only in moist places, their sperms are flagellated and water is required for fertilization.Young sporophyte develops directly from the zygote without passing through any protected seed like stage.

ALTERNATION OF GENERATION

- Life cycle is completed in two stages or generations known as Gametophyte and Sporophyte.
- The two generations differ from each other in morphology, reproduction and number of chromosomes.
- The gametophyte is haploid and reproduces sexually by forming the gametes. The sporophyte is diploid and reproduces asexually by forming the spores.
- The two generations regularly alternate with each other and therefore, the phenomenon is called "Alternation of generation" (Heteromorphic).

- In Bryophytes, the main plant itself is the Gametophyte while the sporophyte is reduced.
- In Tracheophytes, the main plant is "Sporophyte" and the "Gametophyte" is reduced.

GYMNOSPERMS

Introduction: The Gymnospems form a bridge between the Pteridopyhyta and the Angiosperms. They are older than the Angiosperms. The method of reproduction in Gymnosperms indicates that the flower of Angiosperms may evolve from the Gymnoseprms. The reproductive organs of Gymnosperms are aggregated into flowers (cones). However, these flowers differ from those of the Angiosperms. In Angiosperms, the female reproductive organ or ovule is enclosing in a special protective structure, the *carpel*. In Gymnosperms are exposed on *megasprophylls*. Hence, the term Gymnosperms is called 'naked seed plants'. Gymnosperms are of great economic importance as source of timber resin and turpentine. Among the best-known Gymnosperms are the pines (*Pinus*), spruces (*Picea*), firs (*Abies*), junipers (*Juniperus*) etc.

General characters:

1. The Gymnosperms are *woody*, *perennial* forms. Plants are either *trees* or *shrubs*. There are mostly evergreen trees. They lost their leaves in winter. They are adapted to xeerophytic habit.
2. They have well developed *tap root* system. It provides a better anchorage and facilitates absorption of water.
3. The leaves are dimorphic, scale leaves and foliage leaaves. Scale leaves are brown in colour and memranous. Foliage leaves are evergreen and show cyclic arrangement (*Cupressus*) or spiral arrangement (*Pinus*).
4. The roots have *radial* vaascular bundle with exarch xylem. It may be diarch, triarch or tetrach.
5. The stem has *conjoint* and *collateral* vascular bundles with *endarch* xylem. The vasuclar bundles are arranged in a ring as in dicot stems to produce unlimited growth. In *Pinus,* the pith is very much reduced. In *Cycas* the pith is well developed.

6. The xylem except Gnetales consists exclusively of *pitted tracheids*.
7. The phloe m is devoid of compainon cells.
8. The reproductive organs form strobili or cones. They are male (microsporangiate) or female (megasporangiate) i.e., unisexual.
9. The megasporangia (ovules) are borne on the surface of the megasporophyll. They are orthotropous.
10. The female gaemtophyte consits of a well-developed *endoserpm*, it has two or more archegonia. Neck canal cells are absent.
11. The male cones are short lived. The microsporangia are found on the lower side of the microsprophyll. They are numerous and form sori in *Cycas*. In *Pinus,* only two microsporangia are found on each microsporoplyll.
12. The male gametophyte is reduced and contains one (*Cycas*) or two (*Pinus*) prothallial cells.
13. The male and female gametophytes are reduced and are dependent upon the sporophyte. They develop within the tissues of the sporophyte.
14. The pollen tube grows through the female gametophyte and reaches the archegonium. Feretilization results in the formation of oospore.
15. The oospore develops into an embryo. *Polyembryony* is common. The megasporangium changes into a seed. Fruit like structures are not found in Gymnosperms, as the ovules are not enclosed in ovary.
16. The seed contains two or more cotyledons and on germination gives rise to the plant body.

Distribution: The total number of living Gymnosperms in the world is approximately 70 genera and 752 speceis. Raizada and Sahni (1960) report 16 genera and 53 species are in India. Lesser representation in India is because Gymnosperms are maily preferring temerate regions and in India, such a climate is present inly in the Himalayas.

There are six living orders of Gymnosperms and out of them, four are represented in India. These include *Cycadales, Coniferales, Ephedrales* and *Gnetales. Ginkgo biloba* (*Ginkgoales*) is cultivated at many places in India but it originally belongs to China.

The *Cycadales* are represented by four species of *Cycas* in India. *C. circinalis* found wild in the dry deciduous forests of South India. *C. pectinata* grows wild in several parts of Eastern India. *C. rumphii* grows in Andaman and Nicobar islands. *C.revoluta* is a Japanese species, that is, cultivated as an ornamental plant in Indian gardens and is propagated vegetatively by means of bulbils.

The *Coniferales* are represented by eleven genera in India. All of them except *Podocarpus* are restricted to the Himalayas. Some of them occur in both the Eastern and Western Himalayas. They form characteristic formations and their distribution is governed mainly by altitude. *Pinus roxburghii* grows luxuriantly at 1,000 meterss above sea level. *P.wallichiana* and *Abies pindrow* grow at 2500 meters above sea lefvel in the Western Himalayas. *Cupressus sempervirens* and *C.funiberus* are cultivated as ornamentals in Indian gardens. *Larix griffithiana* is the only deciduous conifer of India thata grows in Sikkim,Tibet and Bhutan. *Podocarpus* grows wild in the Andaman Islands and in Eastern Himalayas. It is a graceful tree growing up to 900 meteres and is found in the evergreen climax forests commonly. *Callitris cupressi* was introduced into Nilgris. *Thuja occidentalis* and *Araucaria cookii* is cultivated as an ornamental plant in North India.

Ephedra is represented by six species in India. They grow at high altitudes in the Himalayas. *E.foliata* is a scrambling shrub growing wild in drier parts of Rajasthan.

Five species of *Gnetum* grow in gvarious parts of India. *G.ula* is very common in the evergreen forests of Western Ghats, Andhra Pradesh and Orissa. It is a woody climber. *G.contractum* grows in Nilgiri hills and Kerala.

Classification (Sporne): Gymnosperm classification proposed by Sporne (1974).

K.R. Sporne (1974) adopted classification of Pilger and Melchior (1954) and recognized following three classes and nine orders:

1. **Cycodopsida:** Pteridospermales, Bennettitales, Pentoxylales and Cycadales.
2. **Coniferopsida:** Cordaitales, Coniferales, Taxales and Ginkgoales
3. **Gnetopsida**: Gnetales

Cycodopsida:

1. Palaeozoic Pteridosperms – Mezozoic Bennettitales –Jurassic Pentoxylales – Mesozoic Cycadales
2. The plants have erect,slender or weak stems.Palm like habit in Cycadales.
3. The leaves are large, pinnately compound, armour of persistent leaf bases in Bennettitales, thick simple and lanceolate leaves in Pentoxylales.
4. Solid primary xylem. Protostele is mesarch,
5. Secondary wood and phloem were formed in smaller amounts
6. Tracheids of secondary wood have multiseriate bordered pits
7. Seeds are produced in cones or inflorescences.
8. Annulus absent in the ovules.
9. Distinct pollen-chamber and a micropyle,Pollen tubes are absent
10. Megaspore is surrounded by a thick wall

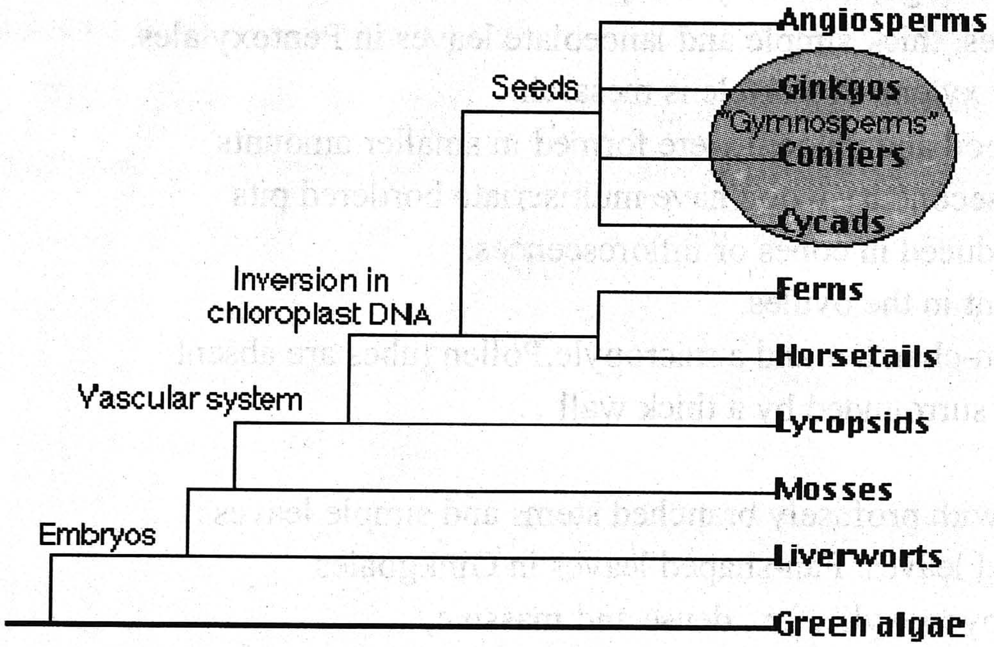
Coniferopsida:

1. Large plants with profusely branched stems and simple leaves
2. Needle shaped leaves. Fan-shaped leaves in Ginkgoales
3. The wood is pycnoxylic, i.e., dense and massive,
4. Resin canals occur in the cortex
5. Seeds are bilaterally symmetrical
6. Unisexual cones
7. Male cones are small, short lived
8. Sperms are with spiral bands of flagella
9. Female cones are compound with scale and ovulifeerous scales
10. Embryo is with two cotyledons in Taxales

Gnetopsida:

1. Climbing shrubs or small trees with branched stems
2. Leaves with broad lamina and reticulate venation
3. Unisexual spike-like inflorescence or cones,
4. Male reproductive organs with perianth and antherophores with 1 to 8 synangia
5. Female reproductive organ is with a single eret ovule
6. Micropyle projects a long tube.
7. Embryo with tow cotyledons

Evolution of Gymnosperms: Gymnosperms are circled in this diagram of plant phyla.



Gymnosperms and angiosperms are the two clades formed by seed plants. The relationships among the four living phyla of gymnosperms (Ginkgophyta, Cycadophyta, Gnetophyta and Coniferophyta) remain unclear.

Archaeopteris is an example of a progymnosperm, a transitional species of seedless vascular plant. Archaeopteris evolved during the late Devonian period, roughly 380 million years ago(MYA). Though it lacked seeds, it possessed some characteristics of seed plants, including heterospory and woody stems. Though now extinct, the first of several lineages of seed plants appeared roughly 360 million years ago. The earliest known gymnosperm fossils are from 305 million years ago, in the Carboniferous era. The Carboniferous was a time of glaciation, low sea level, and mountain building. Also during this time, many plants and animals became extinct due to a change in the climate. This shift was called the Carboniferous Rainforest Collapse. When the climate became less humid, the Carboniferous period gave way to the Permian, and gymnosperms flourished. Seeds of Gymnosperms were protected from the dry climate by thick cuticle and small needle-type leaves with less surface area.

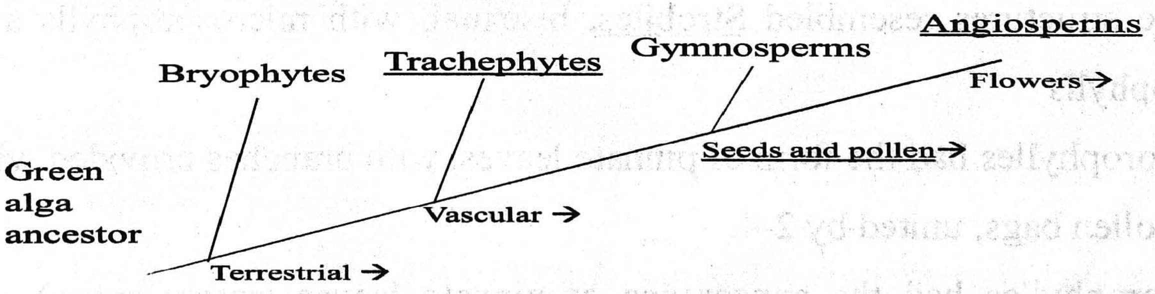
The end of the Permian (251 MYA) is considered the boundary between the Paleozoic (old life) and Mesozoic (middle life). The gymnosperm ecosystems of this era provided food for the huge dinosaurs that dominated on land.

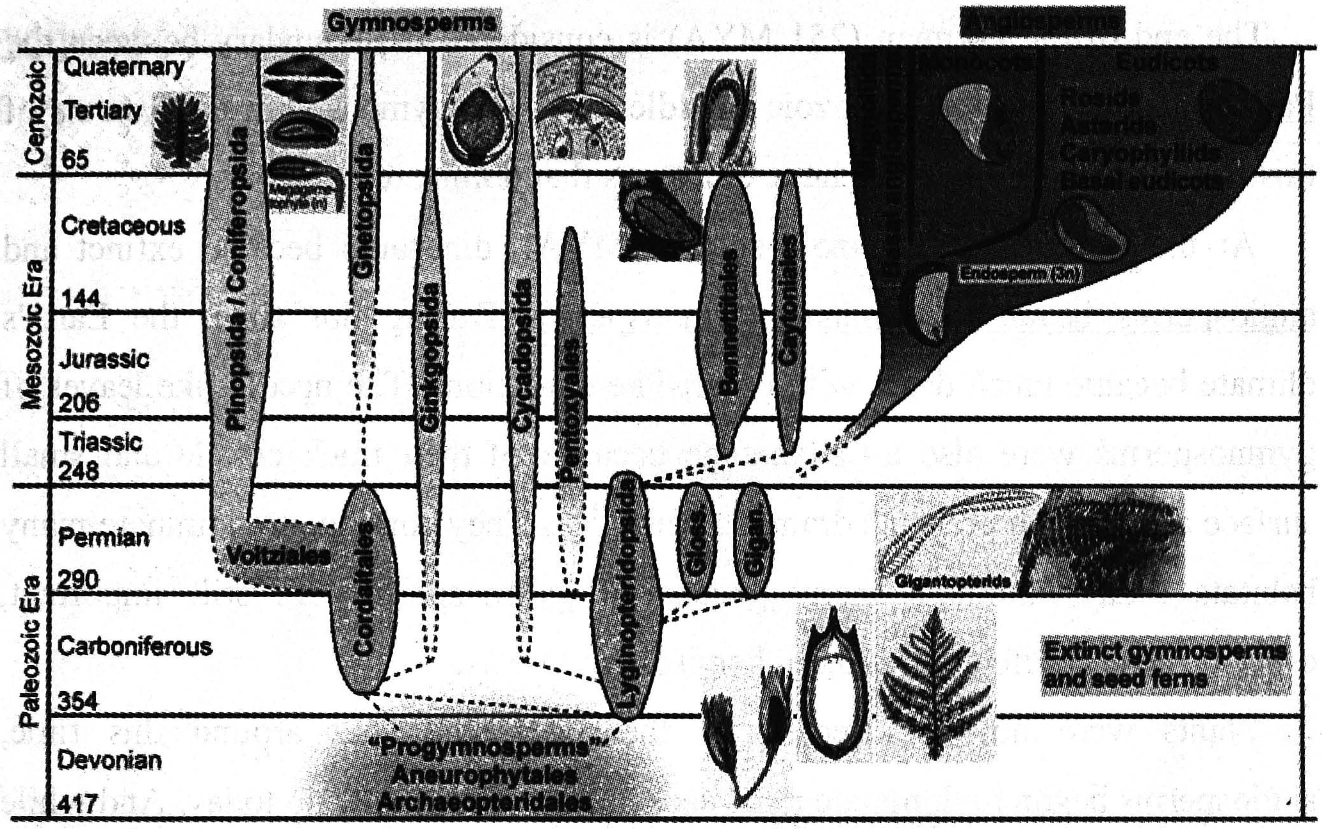
At the end of the Mesozoic era (65 MYA), dinosaurs became extinct and angiosperms began to dominate gymnosperms. During this time, the Earth's climate became much drier, with desert-like conditions. The needle-like leaves of gymnosperms were also an advantage because of their thick cuticle and small surface area, which prevents dramatic water loss.They continue to dominate many habitats today, although many groups of gymnosperms are still important, especially the conifers of northern hemisphere forests.

Plants were not as affected by the extinctions, but around this time, angiosperms began to dominate most ecosystems, just as they do today. And while angiosperms are the more dominant clade, there are still many important gymnosperms, including pines, cedars **and** redwoods

In early classification schemes, the gymnosperms were regarded as a "natural" group. However, now there is conflicting evidence on the question of whether the living gymnosperms form a clade. There is still a debate as to exactly how the phylums within the gymnosperms are related, and which families have a closer relationship to angiosperms.

- **Evolutionary tree of plants**
- **From primitive→ more advanced traits**





Seed plant phylogenetic tree considering major gymnosperm and angiosperm clades. Note that the precise evolutionary connections between the different gymnosperm groups are unknown and that the ancestors of angiosperms are unknown. Typical seed types visualize steps in the evolution of the seed. Extinct gymnosperm groups (fossils): Lyginopteridopsida (seed ferns, "Samenfarne", includes Devonian/Carboniferous Lyginopterids and Carboniferous/ Permian Medullosans and other subgroups), Cordaitales, Voltziales, Pentoxylales. Bennettitales (cycadeoids), Caytoniales, Glossopteridales (glossopterids), Gigantopteridales (gigantoperids). Extant gymnosperm groups: Pinopsida/Coniferopsida (conifers, "Nadelbäume"), Ginkgopsida (ginkgos), Cycadopsida (cycads, "Palmfarne"), Gnetopsida (gnetophytes: Ephedridae, Gnetidae, Welwitschiidae). Angiosperms (flowering plants): Most important groups depicted. Time scale: Geological eras, periods, time in MYBP (million years before present). © 2007 G. Leubner, "The Seed Biology Place", http://www.seedbiology.de

Salient feataures of Pteridospermales:

Pteridospermales (Seed ferns) is a Gymnosperms fossils. Extinct Gymnosperm existed in the Devonian to Carboniferous period. They flourished in the Carboniferous, before disappearing in the Cretaceous.

Their foliage was fern-like in appearance. Morphology, anatomical features resubles ancestor of flowering plants.

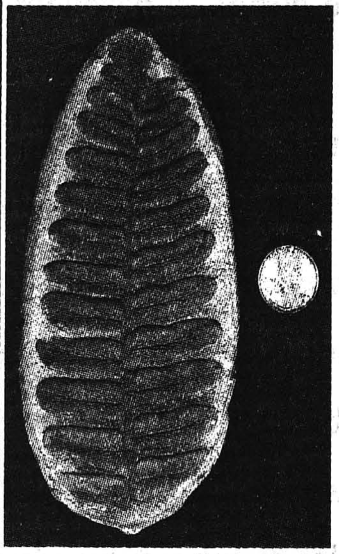
The fertile leaves produce seeds and pollen-producing organs. The reproductive structures resembled Strobiles, bisexual, with microsprophylls and macrosporophylls

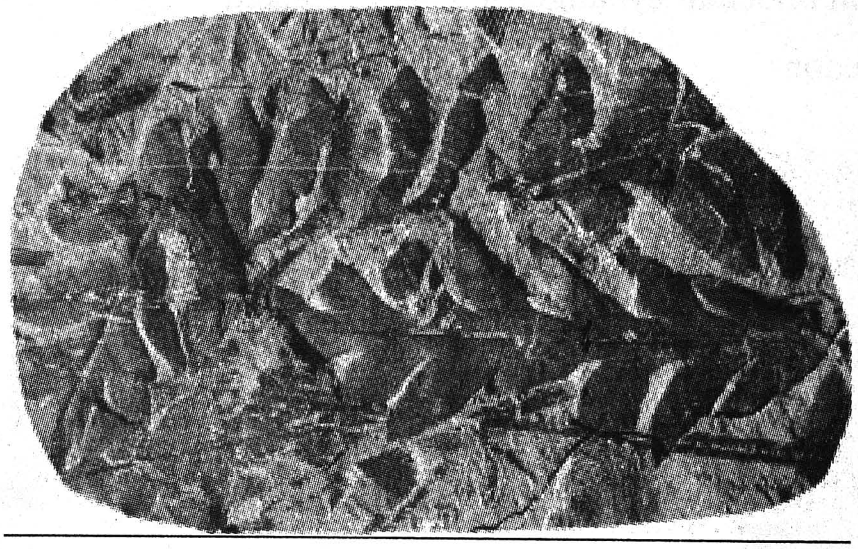
Microsporophylles had the form of pinnate leaves, with branches provided with 2 or more pollen bags, united by 2-4.

Macrosporophylles had the appearance of pinnate leaves (rarely entire), on lobes that were eggs, which were surrounded by involucral formations shaped like cup.

Their seeds were characteristically radially symmetrical; a feature shared by the Cycadales, Bennettitales, and Caytoniales, and thought to indicate that these orders possibly originated from the Pteridospermales

The first plant, *Lyginopteridales oldhamia* was identified in 1903. Some deposits of wood Pteridospermales became important deposits of <u>coal</u> economically exploited.





<u>Salient feataures of Cycadeoidales :</u>

The Cycadeoideales or the Bennettitales is a fossil group greatly attracted the attention of papaeobotanists since 1825. They became fossilised either in the form of compressions or petrifcations.

The petrified stems are columnar, conical with a metre in height. *Cycadeoidea jenneyana* stems have several metres with many branches.

The leaves are large and pinnate compound. In *Williamsoniella,* they are, simple and linear.The pinnae are attached by a broad base to the upper side of rachis.

The venationis parallel. In *Dictoyzamites,* the venation is reticulate. Stomata present.

The stems have large pith surrounded by a ring of collateral conjoint, endarch and open primary vascular bundles. The cortex is parenchymatous and possesses mucilage canals.

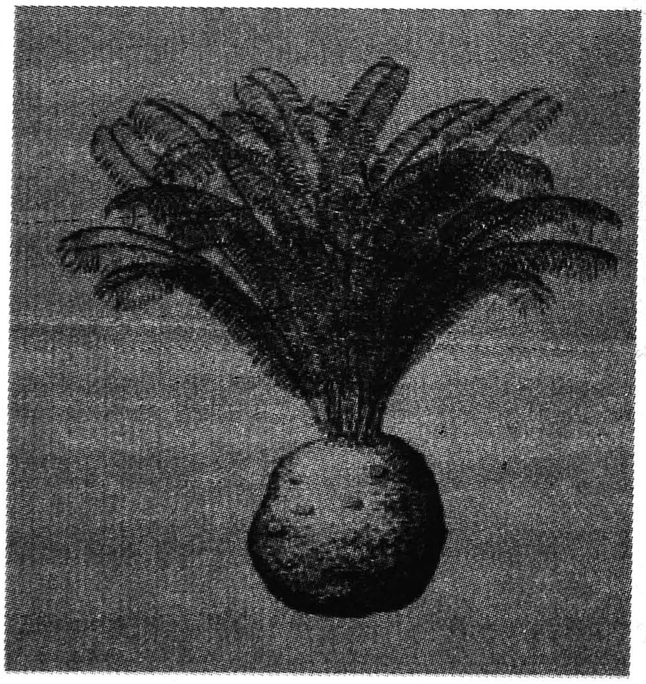
The reproductive organs are bisexual (*Cycadeoidea, Williamsonie*lla) and unisexual (*Wielandiella angustifolia*). The reproductive organs are called flowers. The ovules and seeds are stalked (*Williamsonia*) or sessile (*Williamsoniella*).

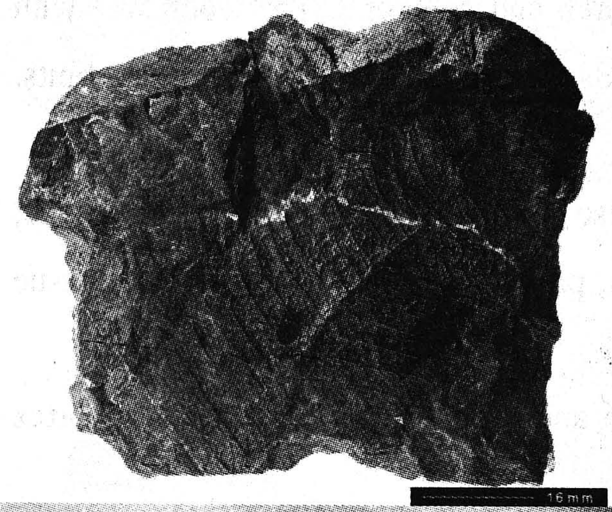
The ovules are not enclosed in a cupule, i.e., the cupule is absent.

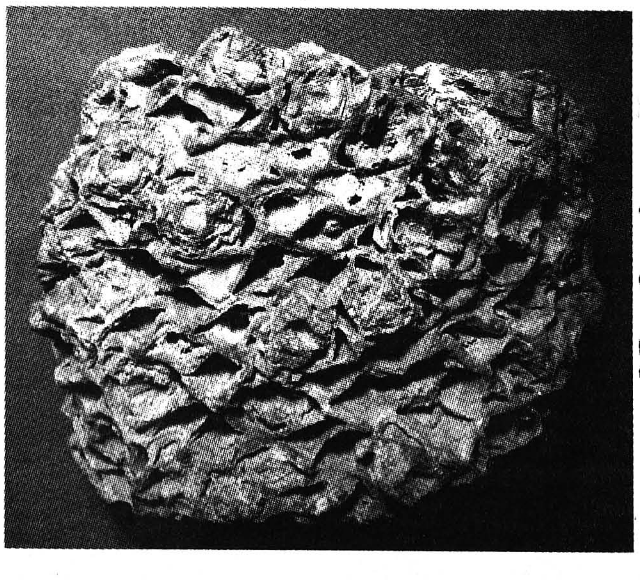
The microsporophylls or pollen bearing organs arise in whorls entire (*Williamsoniella*) free or fused (*Williamsonia*).

The pollen grains are borne in bilocular synangia, sessile or stalked

The seeds possess two cotyledons.




16 mm



Salient feataures of Cordaitales:

The Cordaitales were group of Paleozoic Gymnosperms appeared late in the Devonian, made their greatest display during the upper Carboniferous and almost disappeared before the end of the Permian.

The cordaitales were tall and slender trees, branching with a crown of branches after reaching a height of 10 to 30 metres.

The stem shows a large discoid pith, a thick or thin vascular cylinder and a small cortex. Vascular bundles were endarch and collateral. The wood was with narrow uniseriate medullary rays. Tracheids were with multiseriate-bordered pits. The pits were hexagonal in outline.

The structure of leaves is like those of the Cycads. A thick cuticle, Sclerenchymatous upper and lower cortex, palisad tissue and loose spongy tissue were present.

The root was triarch. Secondary xylem and fungal hypahe in the inner cortex were present.

Two kinds of strobili were found on the same plant (monoecious), cluster on lateral branches. The strobilus consists of a short woody axis with terimial pollen sacs or ovules.

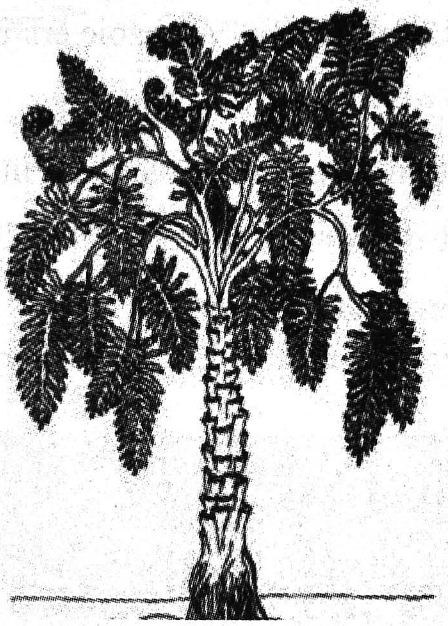
The male strobilus consists of central ais with spirally arranged bracts and microsporophylls.Each stamen (microsporophyll) consiststed of a slender stalk with 3 to 6 erect sporangia.

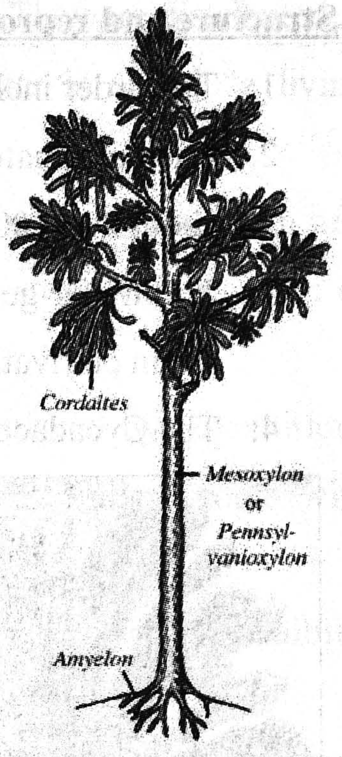
The ovulate strobilus is made up of 1 to 4 ovuliferous appendages (megasporophylls), with terminal ovule.

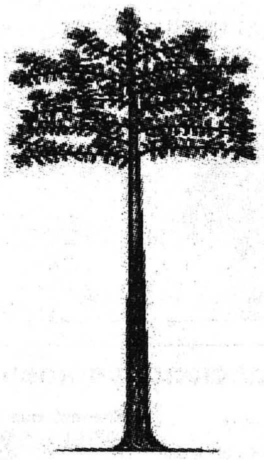
The pollen grains are globoid bodies with 100 microns. The wall was heavilycutinised exine. The air sac of the pollen grains facilatate disperesal by wind.

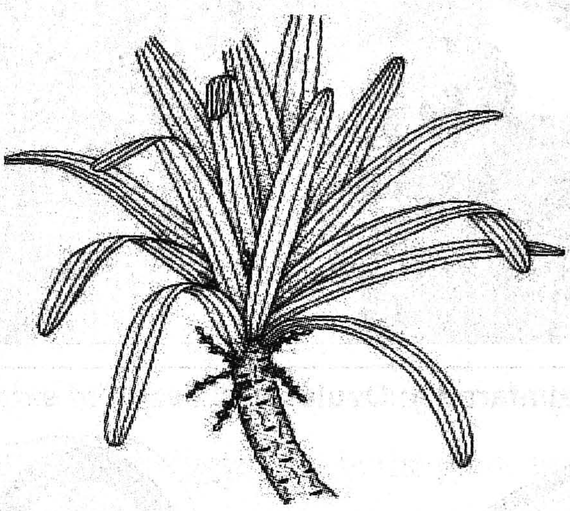
The female gametophytes resemble those of modern Gymnosperms.

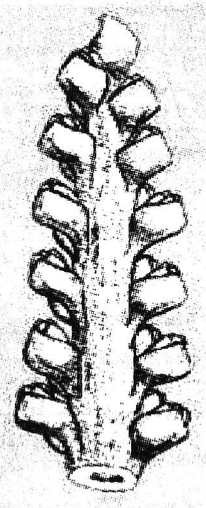
No seeds were found with embryos.




Cordaites
Mesoxylon
or
Pennsyl-
vanioxylon
Amyelon

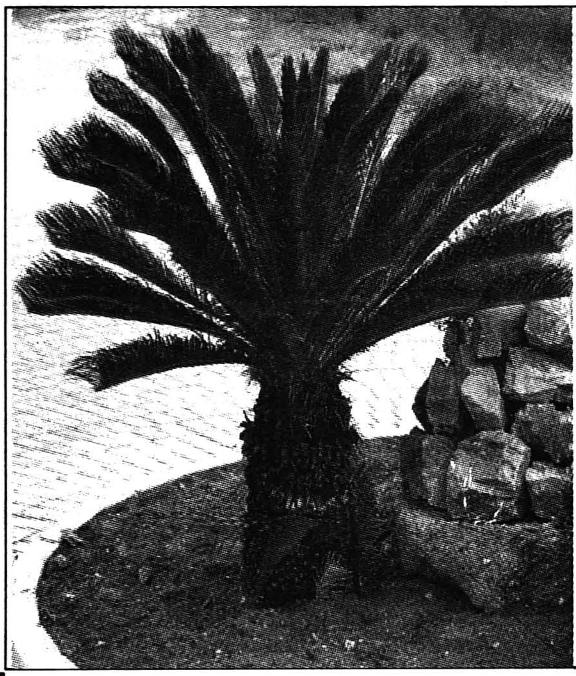


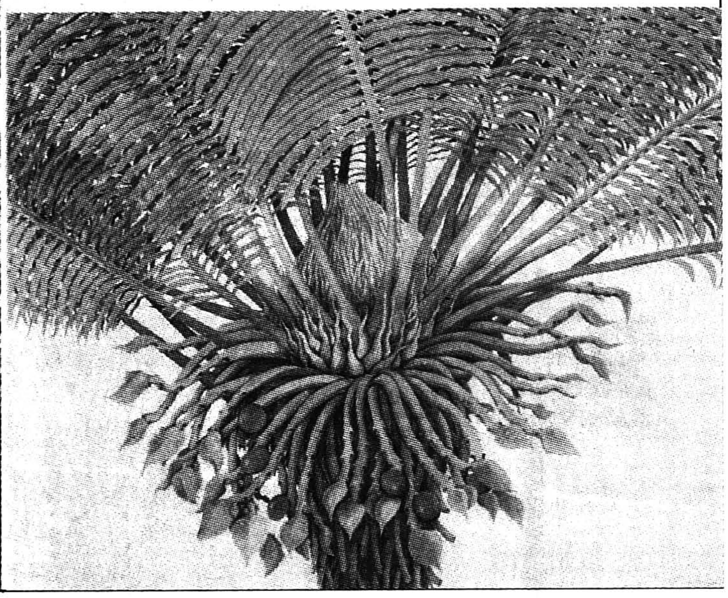




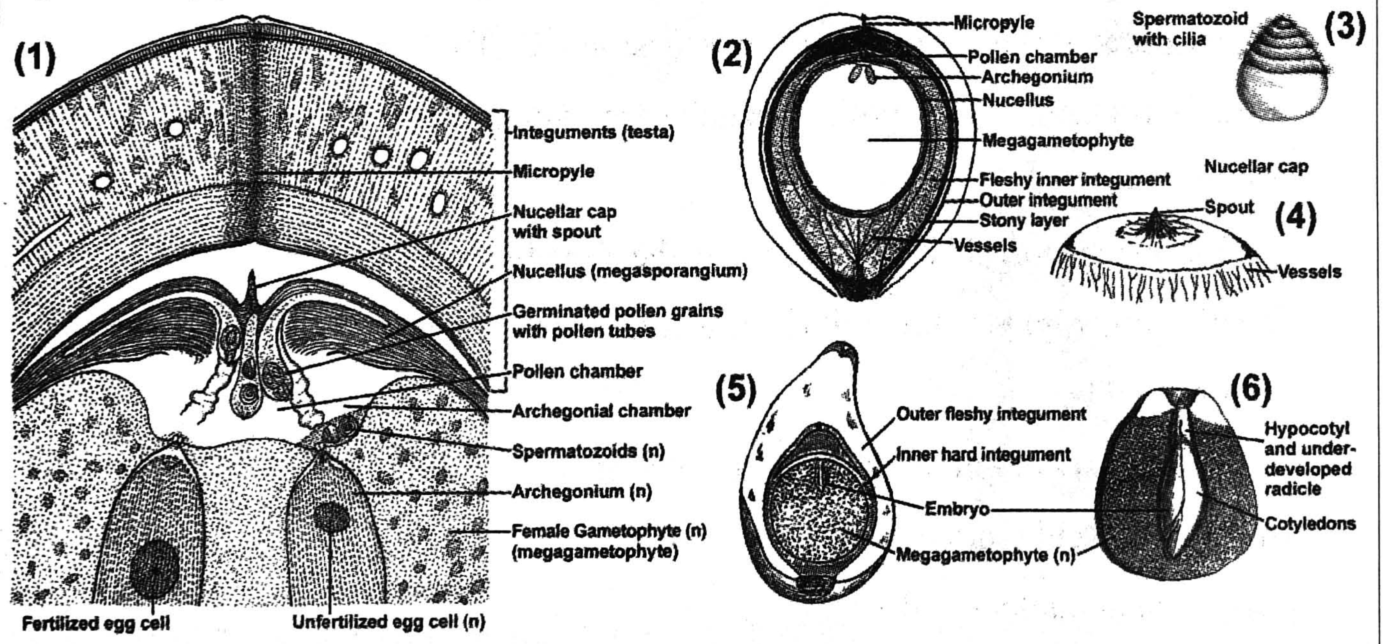
Structure and reproduction in Cycadales :

1. The order includes both living and extinct forms.
2. They originated in the upper Triassic period of the early Mesozoic era i.e., about 200,000,000 years ago.
3. The living genera have attracated the attention of man and many of them are in cultivation and saved from the danger of extinction.
4. The Cycadaceae include 10 living and one fossil genera.





Cycadales (cycads, "Palmfarne"): Ovules and seeds of extant ancient gymnosperms



Cycadales seeds: (1) *Dioon edule* - upper part of a cycad ovule at the time of fertilization. (2) *Cycas circinalis* - ovule (unripe seed). (3) *Zamia floridana* - free swimming mature spermatozoid. (4) *Encephalartos hildebrandtii* - nucellar cap. (5) *Zamia integrifolia* - immature seed. (6) *Cycas circinalis* - mature seed. Drawings by Chamberlain (1), Stopes (2,4), Weber (3), Richard (5,6). From: (1,5,6) Engler (1926), Die natürlichen Pflanzenfamilien, Vol. 13, Gymnospermae. Verlag von Wilhelm Engelmann, Leipzig. (2,4) Schnarf (1937), Handbuch der Pflanzenanatomie, Vol. X/I, Anatomie der Gymnospermen-Samen. Verlag von Gebrüder Borntraeger, Berlin.

Cyas is most widely distributed. It has about 16 species. They are distributed in Japan, Australia, India, China and Africa. *Cycas revoluta* is called "a living fossil".

The plant body of Cycas is a sporophyte, differentiated into root; stem and leaves.The plant has a thick, erect, columnar, unbranched stem with a crown of pinnately compound leaves athe top.

There is a well-developed taproot ststem. Later it is replaced by adventitious roots. A large dichotomously branched, greensih brown coralloid roots with bacteria, blue green algae and fungi are also present.

Cycas reproduces vegetatively by means of large vegetative buds, the bulbils. The bulbils give new plants of *Cycas*.

The plants are dioecious. The sporangia are borne on sporophylls. The sporophylls form cones or strobili.

The male cone develops terminally on the stem. The microsporophylls (stamens) are spirally arranged on a central axis. Sporophylls have microsporangia or pollen sacs. The mature sporangium disintegrates the wall and microspores easily fall out.

The female cone of *Cycas* has spirally arranged megasporophylls. The ovules (megasporangia) of Cycads are the largest in the plant world. At the apex, nucellar beak is present. It has pollen chamber in which the pollen grains collect after pollination.

The megaspore is the first cell of the female gametophyte. It germinates into female gametophyte (prothallus). It is totally dependent on the sporophyte. It lacks chlorophyll.

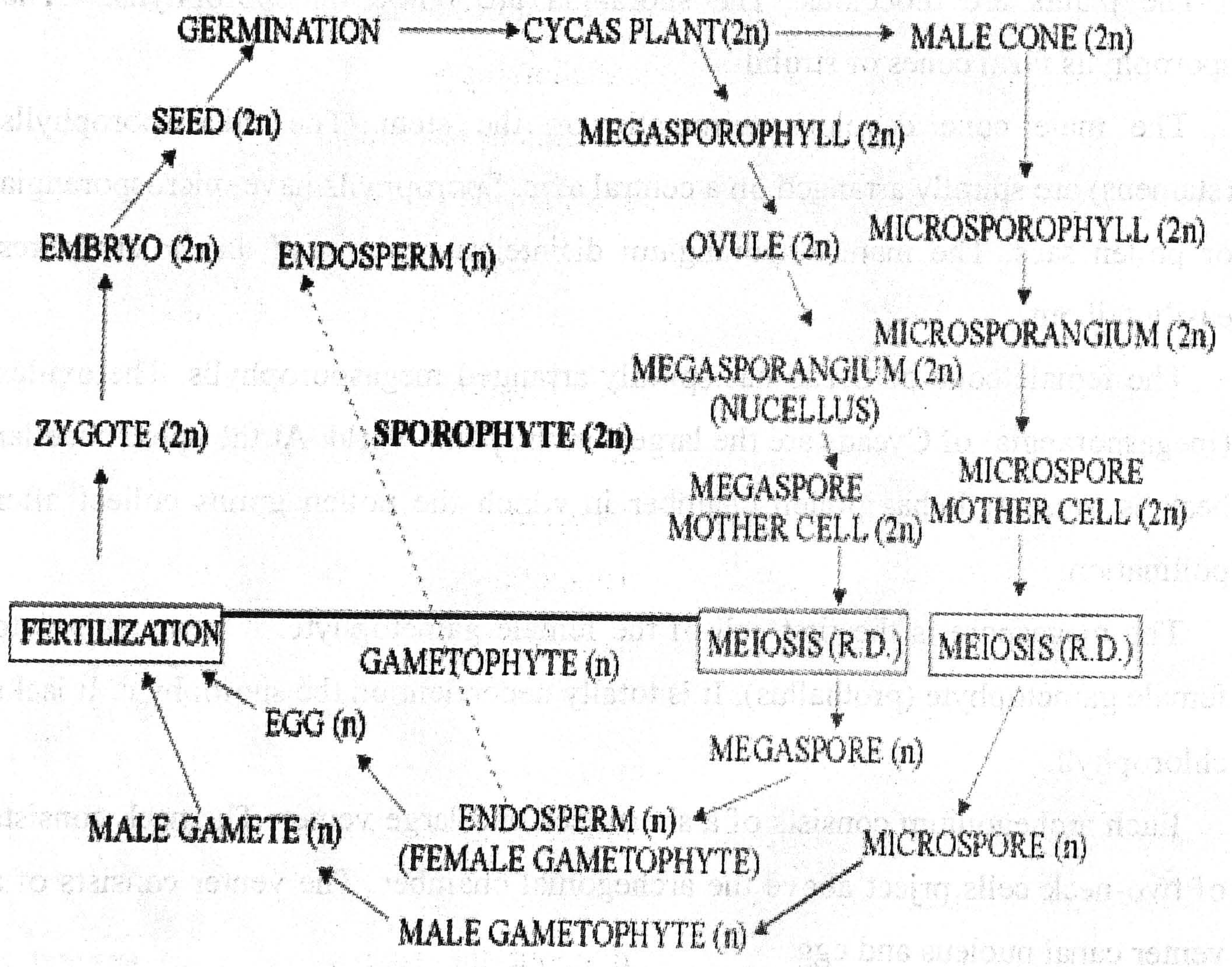
Each archegonium consists of a short neck and large venter. The neck consists of two-neck cells prject above the archegonial chamber. The venter consists of a venter canal nucleus and egg.

The microspore is the first cell generation of the male gametophyte. It germinates into prothallial cell and large antheridial cell. The antheridial cell divides into prothallial cell and tube cell. At this three-cell stage, the pollengrain is shed from the microsporangium.

Pollination takes places by wind. The pollen grains are deposited directly on the pollen chamber. The pollen tube develops and hang down the sperms swim in the pollen tube liquid enter the neck of the archegonia and fuses with egg. Sometimes more than one sperm penetrate the egg called *polyspermy.*

After fertilization, zygote develop into embryo.The proembryo has *haustorial* portion, elongated *suspensor* cells and group of *embryo cells.* The mature embryo consists of a *radicle, plumule* and two *cotyledons.*

The mature seed has a flesh variously coloured outer layer and inner stonly layer. The seed of Cycas is a highly specialized reproductive body. It germinates without rest into new sporophyte.



Structure and reproduction in Ginkgoales :

The remarkable order of great antiquity is represented in the present age by a sole survivor *Ginkgo biloba,* which by many papaeobotanists is regarded as a "living fossil".

It occurred as far back as Triassic period of the Mesozoic age (about 200,000,000 years ago). It consists of 15 extinct genera and one living genus.

The living *Ginkgo biloba* reveals the following characteristics:

The Ginkgo trees are cultivated in Chinese temple gardens as it is considered sacred. A female tree in this late fall attire gives a beautiful look.

The tall tree resembles the conifers with a central shaft and wide spreading branches. with tap root system penetrate deep.

The deciduous foliage leaves and venation resembles the leaves of *Adiantum.* The leaves are fanshaped. The venationis open dichotomous.

The leaves arise singly along the terminal branches and bear in their axils buds that grow into characteristic short shoots, which dense cluster of leaves at their apices.

The plant is dioecious and slow growing

The wood is pycnoxylic. Secondary thickening follows as in *Pinus.*

The strobili of *Ginkgo* are *monosporangiate* and the plants are *dioecious* as in Cycadales. The strobili of both types are *ebracteate.*

The catkin-like inflorescences. It has micro-sporangiophores with 2 to 12 pendent microsporangia arise in the axils of leaves on dwarf shoots. The spermatozoids are motile and bear a spiral band of cilia.

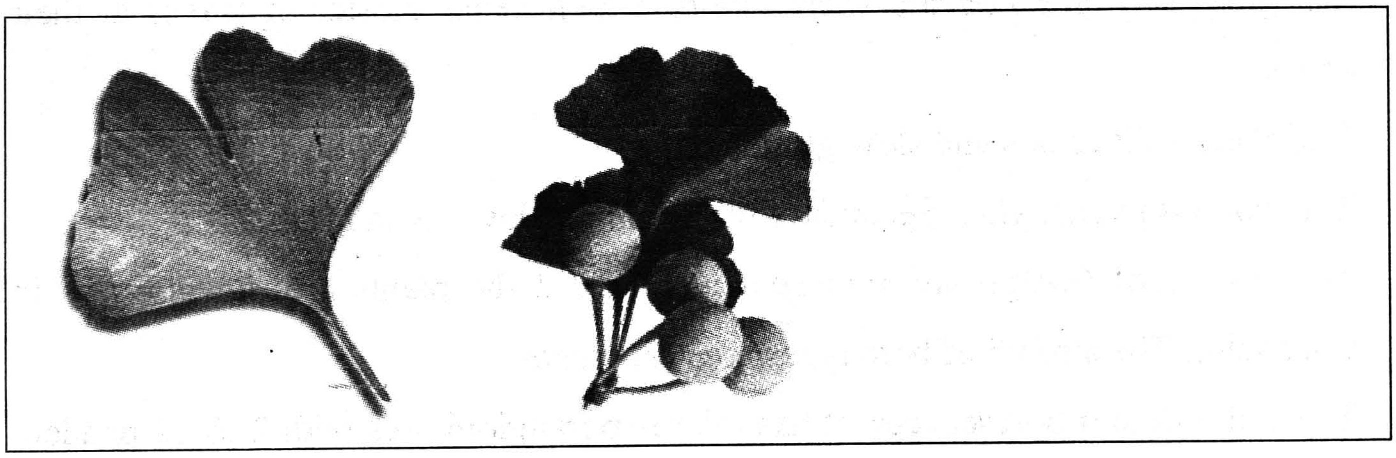
The ovules arise in groups from the apices of axillary branches

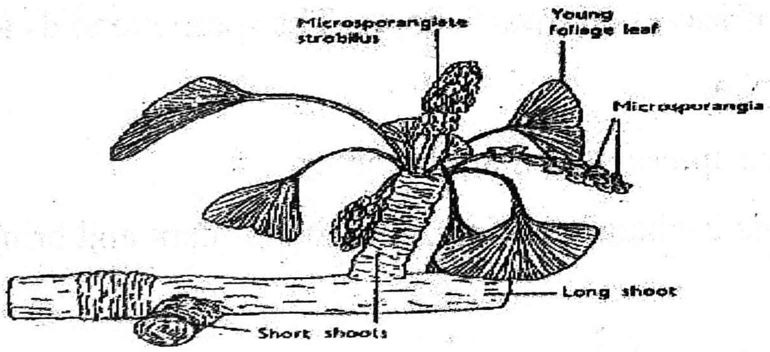
Presence of an endosperm *tent pole* is characteristic of this living plant and brings it akin to the cordaitales.

The mature seeds are large, fleshy and about the size of small apricot. The integument is composed of an outer orange coloured fleshy portion and an inner hard and stony layer.

The fleshy coat is rich in butyric acid and when crushed emitws an odour that is unpleasant.

The seeds produced in large numbers and hang on for a moth or two for the leaves to shed.





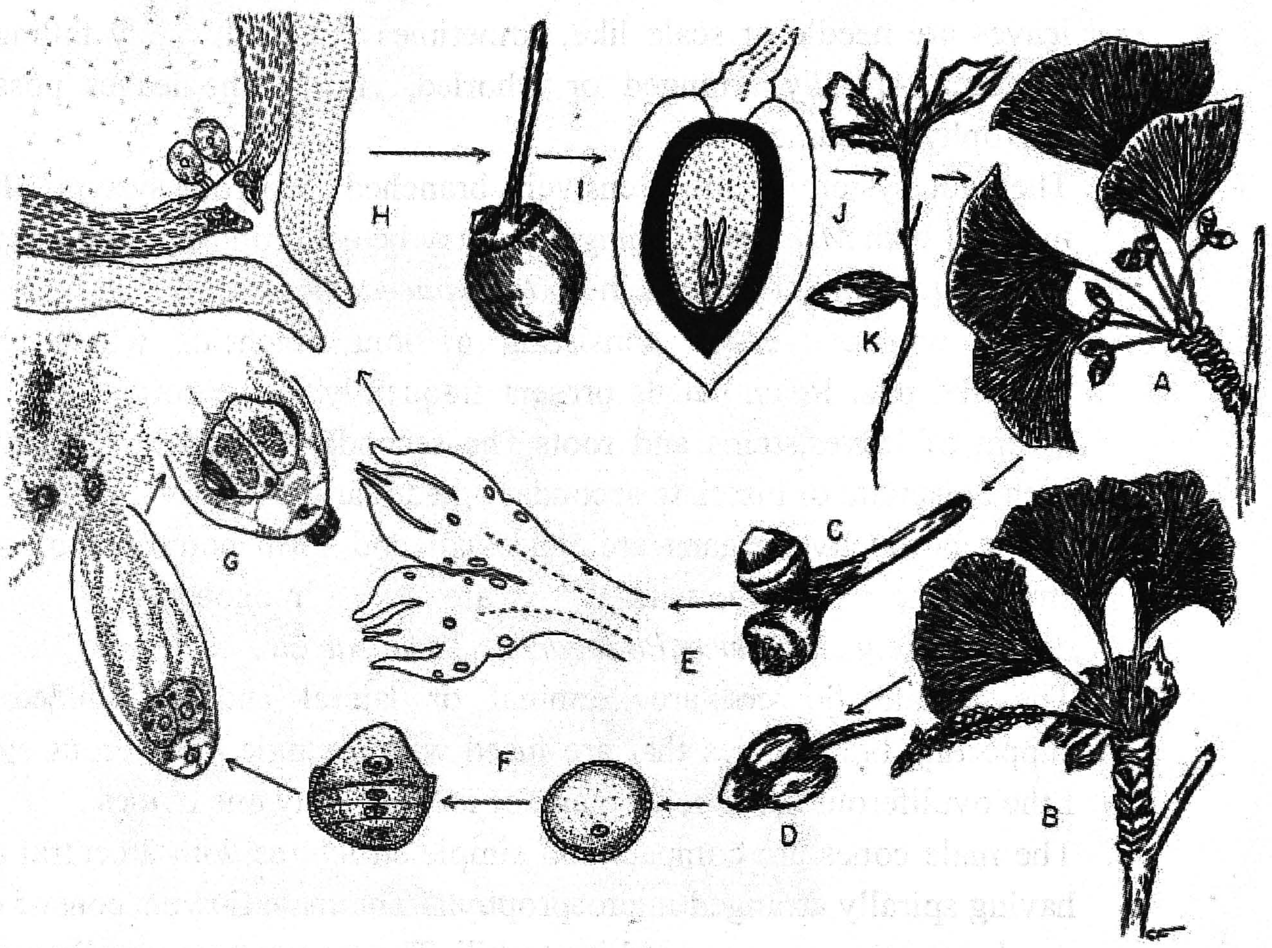
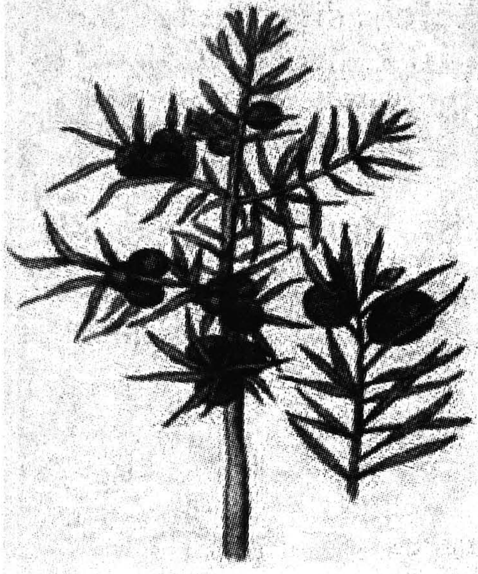


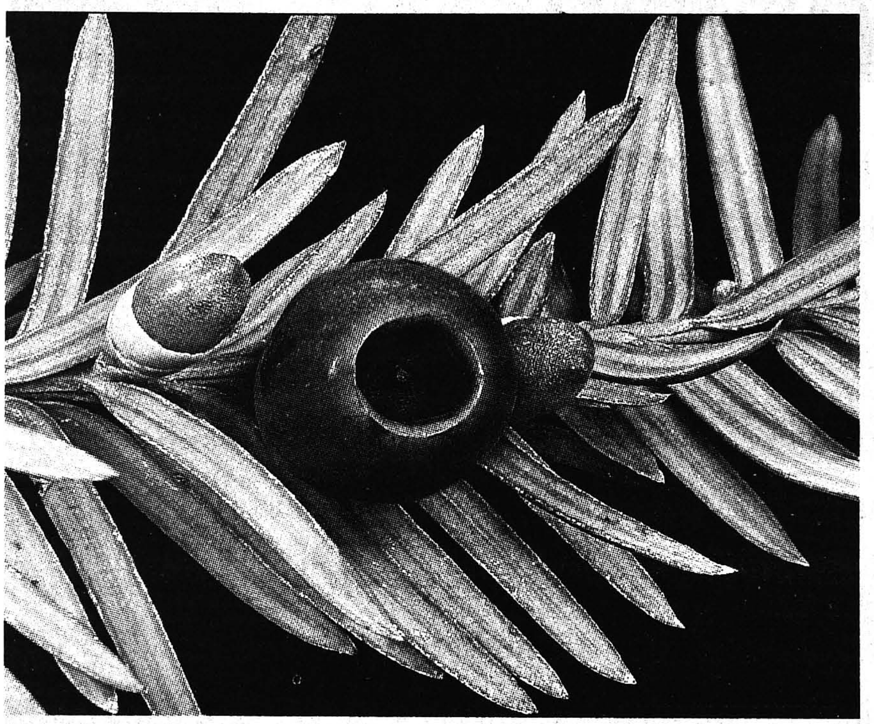
Fig. 22-3 *Ginkgo biloba*, life cycle. A, branch of tree with megastrobili; B, branch of male tree with microstrobilus; C, strobilus with two ovules; D, microsporophyll and sporangia; F, microspores and cells of the microgametophyte; G, sperm, young in drawing at left and ready for discharge at right; H, section of ovule showing two archegonia; I, external view of seed with embryo; J, internal view of seed with embryo; K, young sporophyte. (After Engler.)

Structure and reproduction in Coniferales :

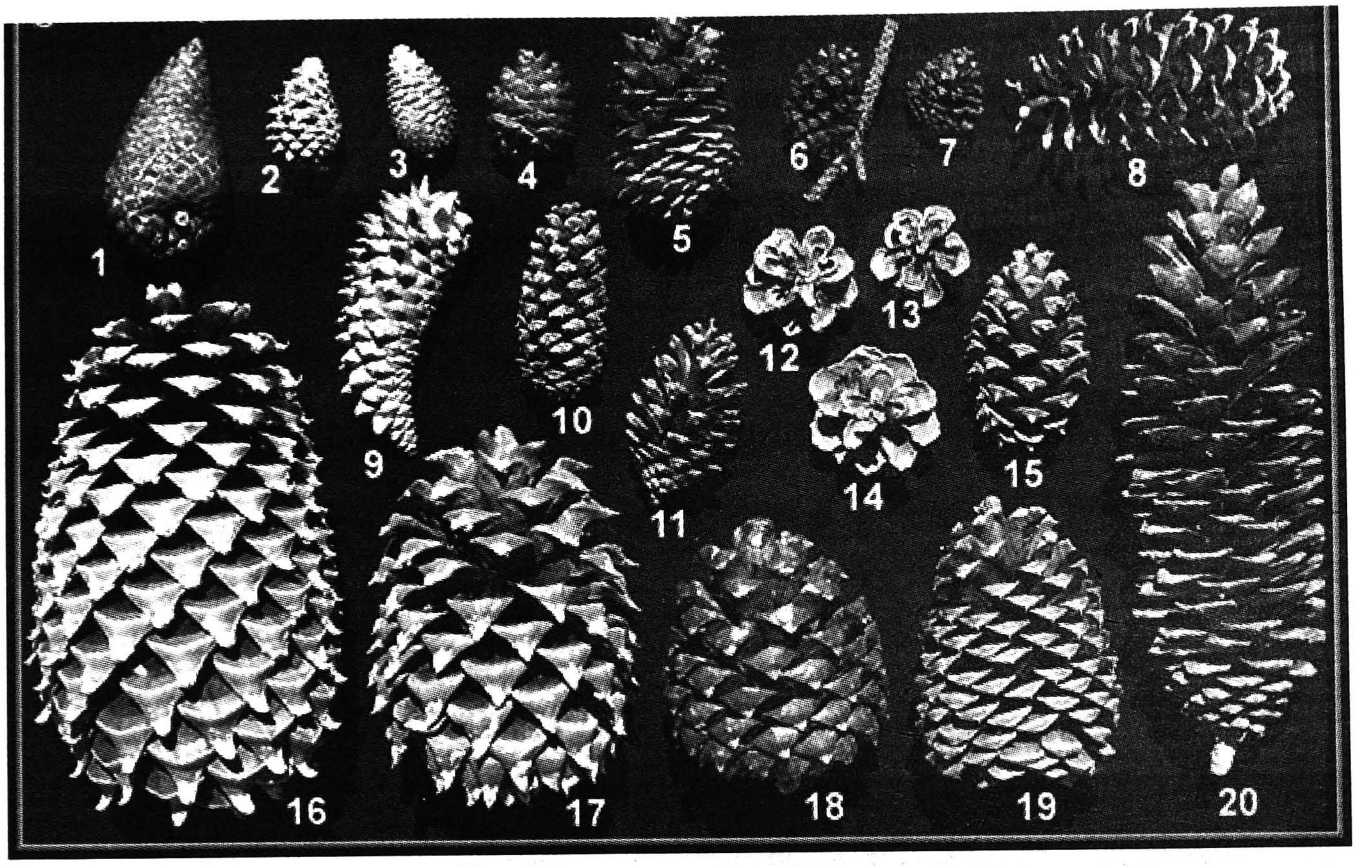
1. Mostly evergreen trees with branched stems, rarely shrubs.The living conifers include 52 genera and 570 species and distributed in temerate regions or in the mountains of the tropics.*Sequoia gigantea* reach a height of 100 metres and lives upto 4,000 years. *Cedrus deodra* grows in India upto 12,000 feet above sea level.
2. The conifers are branching woody plants. Two types of branches: i0 the dwarf shoots, and ii) long shoots.
3. Two types of leaves: i) scale leaves; and ii) green or foliage leaves. The leaves are needle or scale like, sometimes flattened, rarely falling in anutumn, spirally arranged or whorled, entire. The leaves possess xderophytic characters.
4. The root system is an extensively branched tap root system . It is infected with *Mycorrhizic fungus*. I tmay be ectotrophic or endotrophic (*Araucariaceae*). The roots in *Podocarpaceae* possess root nodules.
5. Wood without vessels consisting of long tracheids which show bordered pits. Resin canals present frequently in the cortex, pith and xylem of leaves,stems and roots.The secondary wood in pycnoxylic with uniseriate or biseriate secondary medullary rays.
6. The reproductive organs are unisexual and form compact cones or strobili.The flowers are monoecious or dioecious.,e.g.,*Juniperus,Podocarpus,Taxaceae* etc.
7. The female flowers are terminal or lateral and surrounded by supporting bract scales that are fused with a single ovuliferous scale. Lthe ovuliferous scale bears many or tow or rarely one ovules..
8. The male cones are compact and simple structures with a central axis having spirally arranged microsprophylls.The male flowers consist of a number os stamens arranged in strobili. The stamens are usually many, each with 2 to 20 pollen sacs, connective produced as an appendage
9. Pollen grarins (microsporangia) may be winged,e.g., *Pinus, Abies* ow wingless pollen grains.
10. They produce non-motile sperms at the time of fertilization.
11. The female flowers are arranged in cones or catakins with the exception of Taxaceae, Cephalotaxaceae and Podocarpaceae.
12. The female flower consists of a bract (sterile) and a scale (fertile). The scale is found above the bract. The ovules develop on the upper surface of ovuliferous scales.
13. The female cone ripens in 1-3 years and is usually dry on ripening
14. The seeds are winged, nut like and with a leathery or woody testa.

15. The embryo has two to many cotyledons.
16. The cotyledons are epigeal and 2-16 in number
17. Polyembryony is quite common.

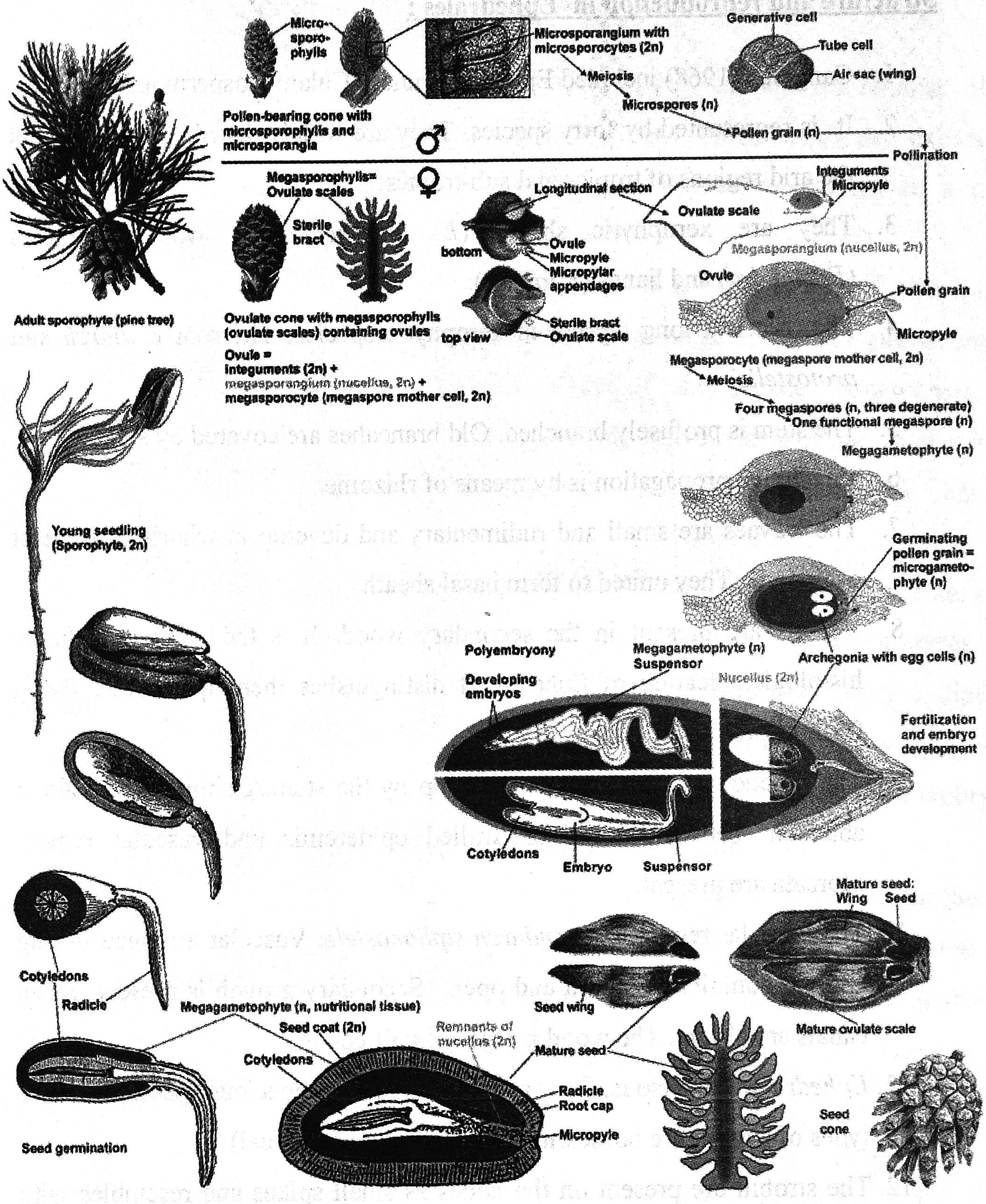




Taxus baccata **shoot with matur and immature cone**



Twenty of the more than 100 species of **Pinus** on earth. All of these pines are native to the state of California, USA. 1. Monterey Pine (**P. radiata**), 2. Bishop Pine (**P. muricata**), 3. Santa Cruz Island Pine (**P. remorata**), 4. Whitebark Pine (**P. albicaulis**), 5. Limber Pine (**P. flexilis**), 6. Beach Pine (**P. contorta**), 7. Lodgepole Pine (**P. murrayana**), 8. Western White Pine (**P. monticola**), 9. Knobcone Pine (**P. attenuata**), 10. Bristlecone Pine (**P. longaeva**), 11. Foxtail Pine (**P. balfouriana**), 12. Four-Leaf Pinyon (**P. quadrifolia**), 13. Two-Leaf Pinyon (**P. edulis**), 14. One-Leaf Pinyon (**P. monophylla**), 15. Ponderosa Pine (**P. ponderosa**), 16. Coulter Pine (**P. coulteri**), 17. Digger Pine (**P. sabiniana**), 18. Torrey Pine (**P. torreyana**), 19. Jeffrey Pine (**P. jeffreyi**), 20. Sugar Pine (**P. lambertiana**).

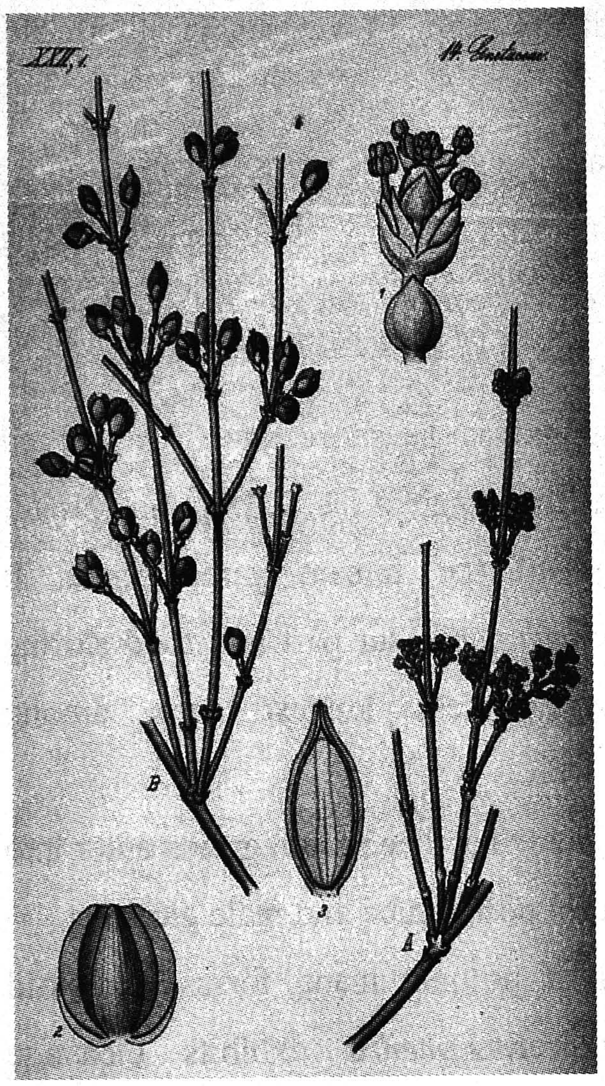

Micro-
sporo-
phylls
Microsporangium with
microsporocytes (2n)
Meiosis
Microspores (n)
Generative cell
Tube cell
Air sac (wing)
Pollen-bearing cone with
microsporophylls and
microsporangia
Pollen grain (n)
Pollination
Megasporophylls=
Ovulate scales
Sterile
bract
Longitudinal section
Integuments
Micropyle
Ovulate scale
Megasporangium (nucellus, 2n)
bottom
Ovule
Micropyle
Micropylar
appendages
Ovule
Pollen grain
Sterile bract
Ovulate scale
top view
Micropyle
Adult sporophyte (pine tree)
Ovulate cone with megasporophylls
(ovulate scales) containing ovules
Ovule =
integuments (2n) +
megasporangium (nucellus, 2n) +
megasporocyte (megaspore mother cell, 2n)
Megasporocyte (megaspore mother cell, 2n)
Meiosis
Four megaspores (n, three degenerate)
One functional megaspore (n)
Megagametophyte (n)
Young seedling
(Sporophyte, 2n)
Germinating
pollen grain =
microgameto-
phyte (n)
Polyembryony
Megagametophyte (n)
Suspensor
Archegonia with egg cells (n)
Nucellus (2n)
Developing
embryos
Fertilization
and embryo
development
Cotyledons
Embryo
Suspensor
Mature seed:
Wing
Seed
Cotyledons
Radicle
Megagametophyte (n, nutritional tissue)
Seed wing
Seed coat (2n)
Remnants of
nucellus (2n)
Mature ovulate scale
Cotyledons
Mature seed
Radicle
Root cap
Micropyle
Seed
cone
Seed germination

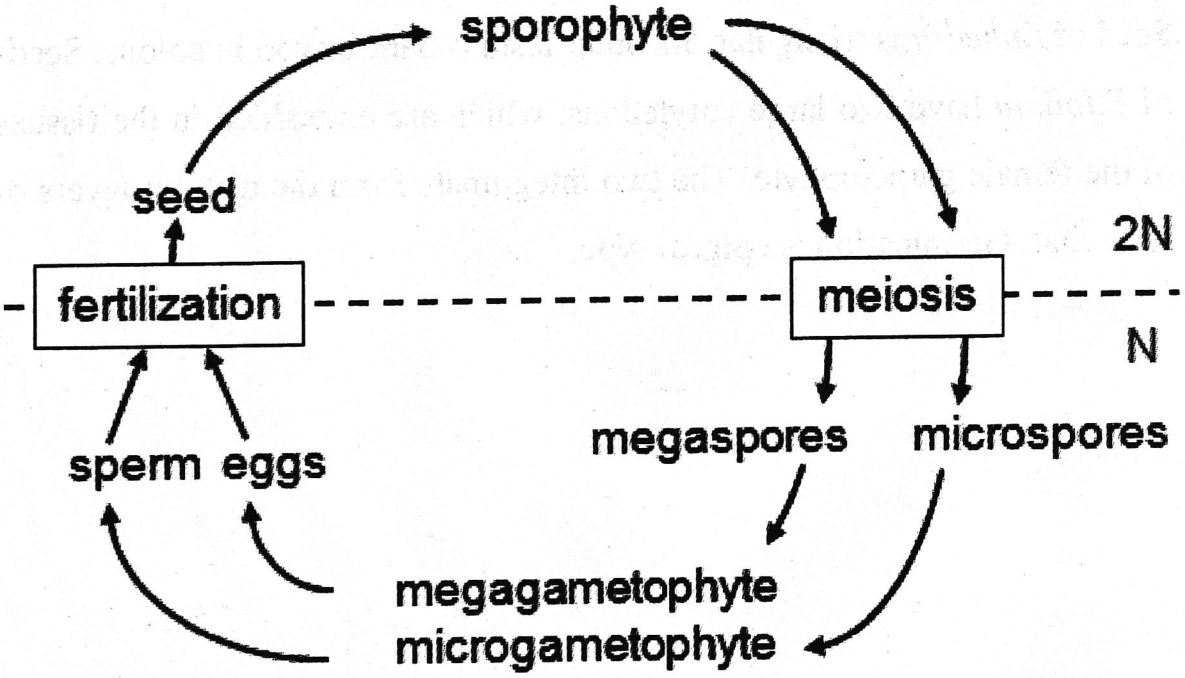
Structure and reproduction in Ephedrales :

1. Cangulae (1968) included Ephedrales under Chlamydospermopsida
2. It is represented by forty species. They are widely distributed throughout the arid regions of tropics and sub-tropics.
3. They are xerophytic shrubs (*E. intermedia*) or woody climbers (*E.triandra*) and lianes (*E.foliata*).
4. The root is a long taproot in xerophytic species. The root is *diarch* and *protostelic.*
5. The stem is profusely branched. Old brancahes are covered by soil.
6. Vegetative propagation is by means of rhizome.
7. The leavaes are small and rudimentary and develop in whorls of three at each node. They united to form basal sheath
8. Vessels are present in the secondary wood. It is the most remarkable histological feature of Ephedra. It distinguishes them from other living Gymnosperms.
9. The function of the leaves is taken up by the stem.Assimilatory tissue ar abundant between the thick walled epideremis and vascular region. Stomata are present.
10. The vascular region is an *endarch siphonostele.* Vascular arranged in ring and are conjoint collateral and open. Secondary growth is present. Resin canals are absent. The wood is highly lignified.
11. *Ephedra* are dioecious, few are monoecious. In dioecious species both the types of strobili are borne on different plants (unisexual)
12. The strobili are present on the nodes as small spikes and resembles with the inflorescence of angiosperms.
13. Male cones are present at each node of the male plant. It has s short central axis with 2 to 8 pairs of bracts.Each bracat has a single male flower. Eacah male flower has short *antherophore* with 1 to 8 anthers at its tip.
14. The female cones are similar to male cones, smaller than the male. It has four pairs of bracts, which fuse to form the *cupule.* They are also called

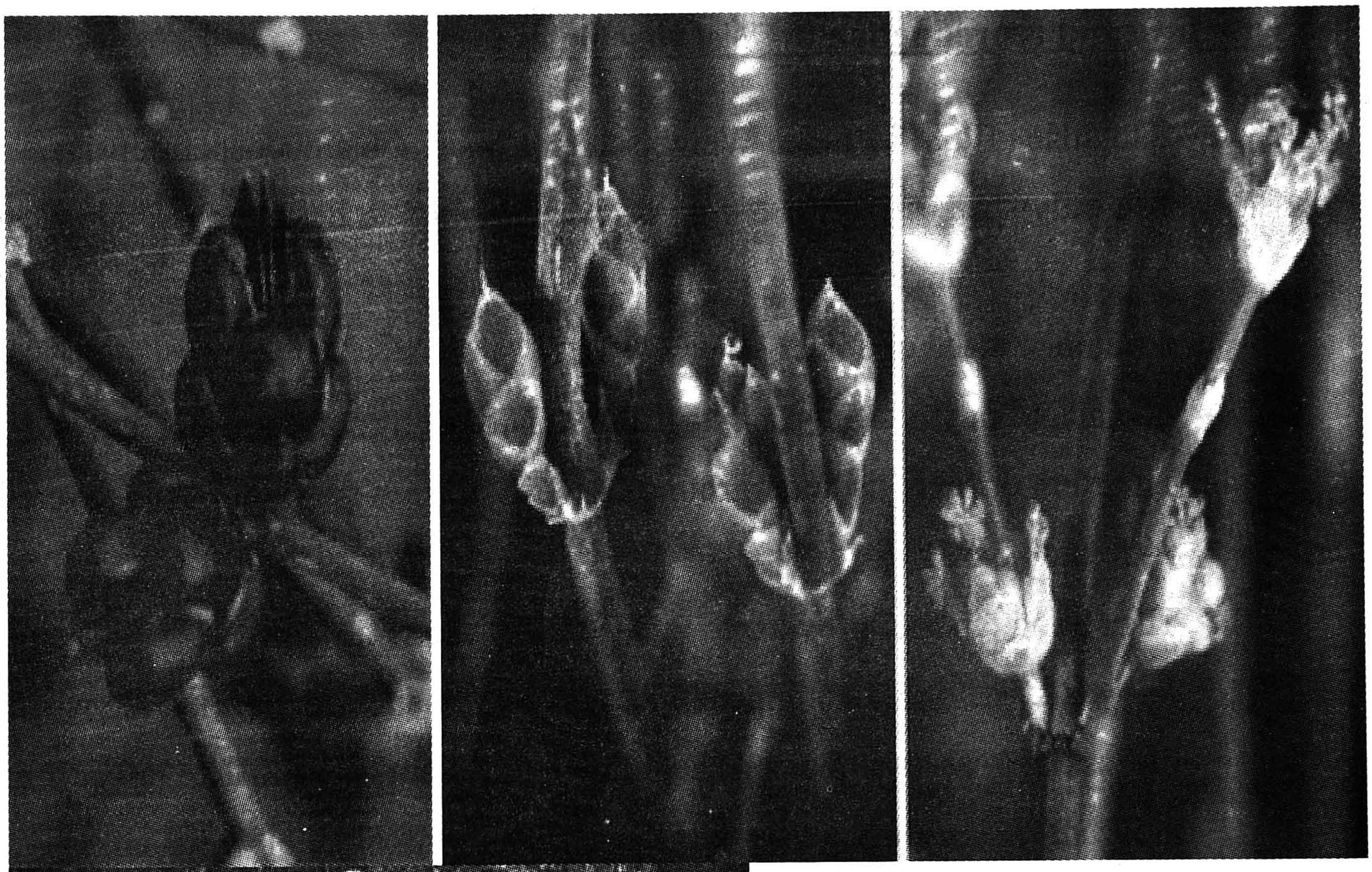
Ovulate Strobilus or Megasporangiate Cone. Lower bracts are sterile. Upper bracts are fertile.

15. The ovule of *Ephedra* is unique among Gymnosperms because of its *bitegmic nature* i.e., two integuments are present. Another interesting feature is the marked *elongation of the inner integument* as a tube, extending out at the time of pollination.
16. The development of the microsporangium is "Eusporangiate". Unwinged boat shaped Microspore represents the first stage of the male gametophyte.
17. The megaspore is the first stage of the female gametophyte. It differentiates into archegonia producing micropylar part and food storing cells of chalazal parts. *Ephedra* possess longest neck among gymnosperms.
18. Pollination is anemophilous type, i.e. by wind. The pollen grains enter into the pollen chamer and germiante to form pollen tube and male gametes
19. Fertilization is over within 12 hrs of pollinationand forms a diploid zygote.Zygote divide into many cells.*Ephedra* exhibits cleavage polyembryony. Each embryo has two cotyledons. Out of all these embryos only one remains in the seed and the rest disintegrate
20. Seed of *Ephedra* is triangular. Its outer testa is dark brwon in colour. Seeds of *E.foliata* have two large cotyledons, which are embedded in the tissues of the female gametophyte. The two integumets form the distinct layers of seed coat. Germination is epigeal type.





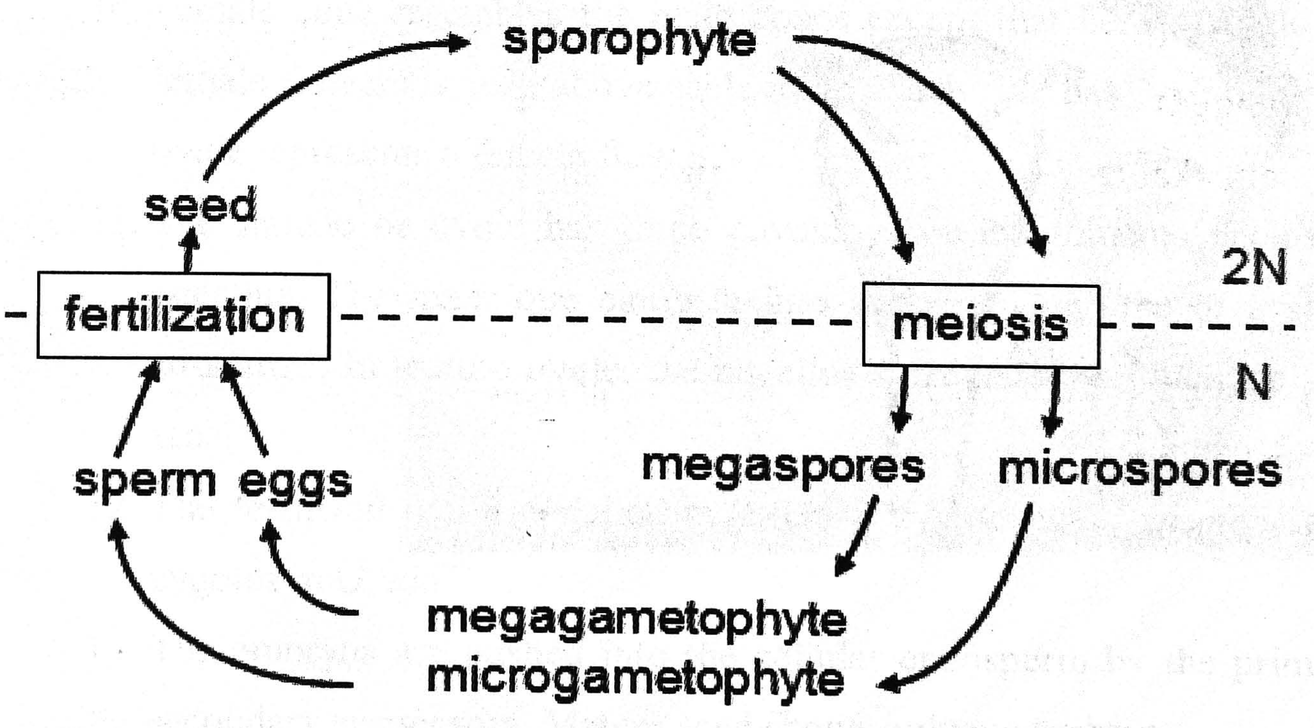
sporophyte
seed
fertilization
meiosis
2N
N
megaspores
microspores
sperm
eggs
megagametophyte
microgametophyte

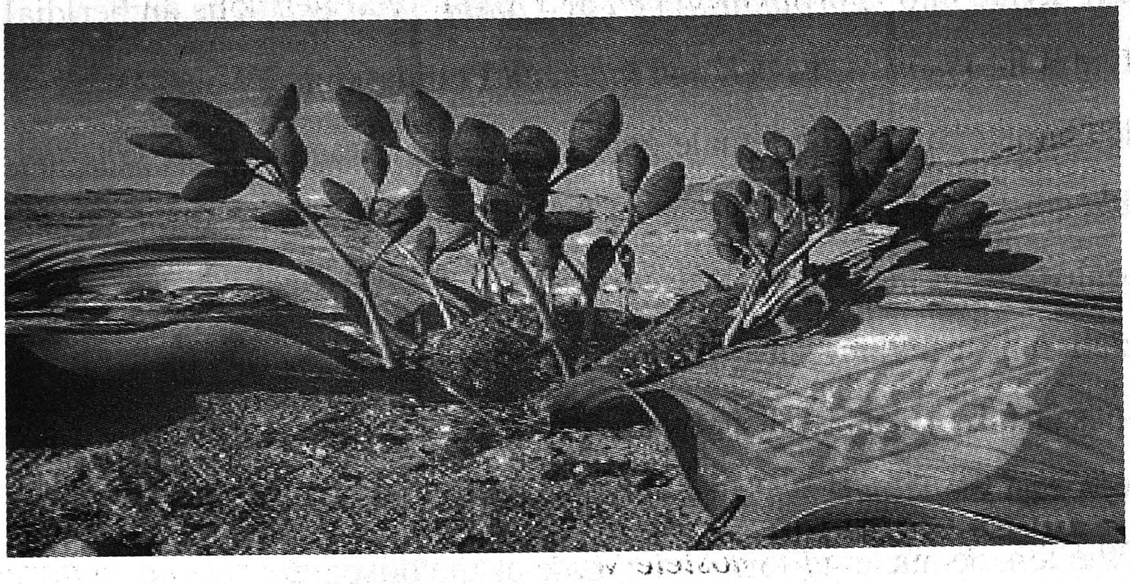


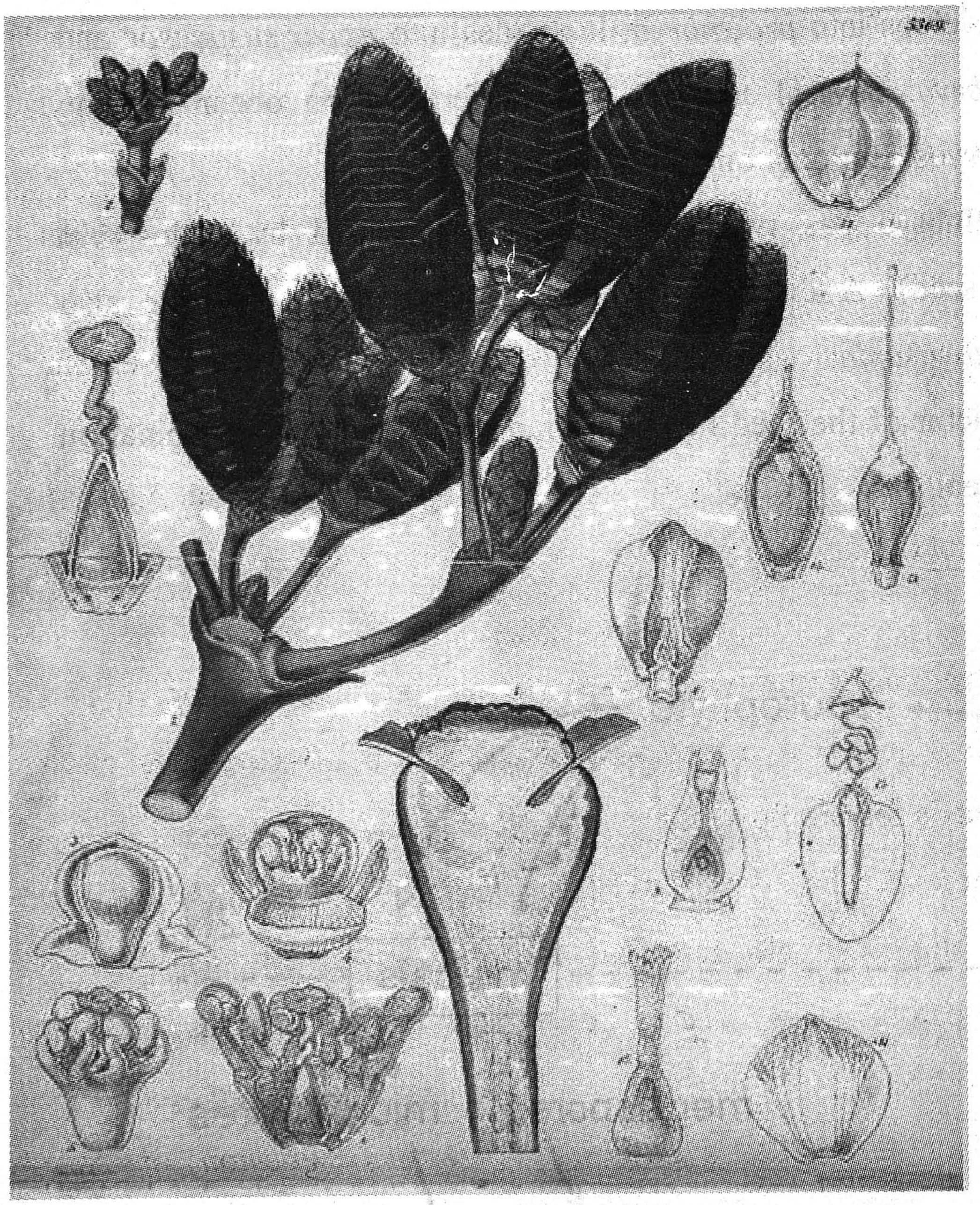
Structure and reproduction in Welwitschiales :

1. Cangulae (1968) included Welwitschiales under Chlamydospermopsida.
2. The only species *Welwitschia mirabilis* is found in deserts of South West Africa. It is an excellent example of a xerophyte where annual rainfall does not exceed one ilnch.
3. The plant body is a Sporophyte differentiated into root, stem and leaves.
4. The stem or 'axis' is underground. It looks like a huge turnip. It is covered with thick bark
5. The strong tap root grows into the deeper of the sandy soil
6. The plant has only two opposite leaves, continue to grow during the whole life as long as two-meters.The life of the plant is estimated to be one thousand years.The leaves are thick, leathery with parallel veination.
7. *Welwitschia* is dioecious and the flowers are borne in inflorescence produced on the crown of the stem.
8. The anatomy of stem is not clear. The bundles are conjoint, collateral and endarch with a cambium. Somethimes the young stem and root show growth rings. In the secondary wood the tracheids have, bordered pits.The epidermis of the leaf is thickly cuticularised with deeply sunken stomata.
9. The microsporangiate and megasporangiate strobili are compound structures.
10. The male flower occurs singly. The flowers appear to be bisexual but functionally they are only male. Each flower consists of six monadelphous (united) stamens, surrounding in the centre a sterile ovary with a remarkably long spirally coiled micropylar tube.
11. The ovulate (Female) strobilus has same general structure as the male strobilus but larger. Each female flower consist of a single ovule with two envelops. Inner envelop is called integument and the outer envelop is called bract or *Perianth*.

12. Male Gametophyte: The wall of the microsproe consists of exine and intine. It divide into a *prothallial cell* and *antheridial cell*. The antheridial cell divides into *generative cell* and *tube cell*.Pollinationis by insects.
13. Female Gametophyte: The female gametophyte is tetrasporic like *Gnetum*. *No archegoia are formed* but some cells in the apical region of the female gametophyte meet the pollen tube.
14. Fertilization is peculiar. One female nucleus moves to the tip of each embryo sac tube. Contact betweenthe pollen tube, the embryo sac tube dissolves, and the female nucleus *migrates into the pollen tube* to fuse with one of the female nuclei to form the zygote or the oospore.
15. The zygote develops into *proembryo*. It divides into upper *suspensor* and the lower *embryo*. Several separate acts of fertilization occur forming numerous embryos. But only one of them mature.
16. The mature embryo has two cotyledons surrounded by endosperm (endospermic seed). A distinct 'feeder' like that of the *Gnetum* also develops in *Welwitschia*.
17. Wing-like structur of the seed helps in wind disperesal. The germination of seed is epigeal.





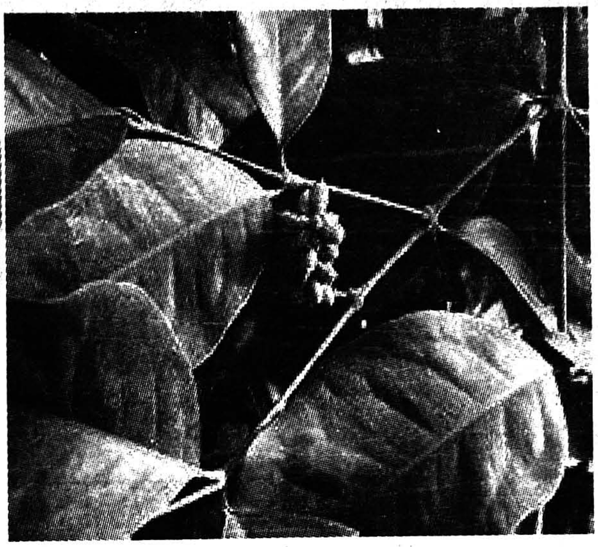


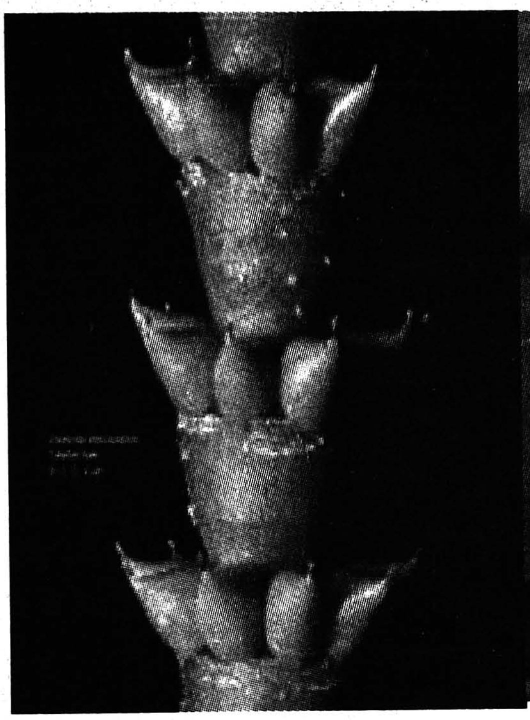
Structure and reproduction in Gnetales :

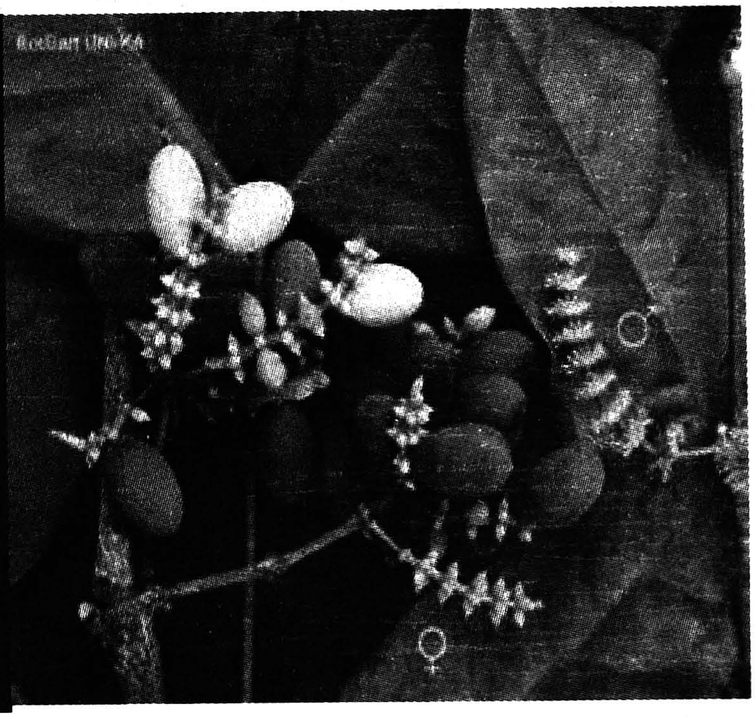
1. Cangulae (1968) included Gnetales under Chlamydospermopsida
2. Represented by 30 species, occurs in South America, Africa, India and China. In India, *Gnetum* is represented by *G. ula*, *G.contraactum*, *G.gnemon*, *G.montanum* and *G.latifolium*. Mostly *climbers* or very large *lianas*.
3. They resemble Angiosperms. The leaves are opposite, reticulate, leathery and broad.
4. Tap root system, Secondary growth is normal.
5. Young stem shows a *Siphonostele* with *conjoint, collateral and endarch vascular bundles.* Abnormal type of secondary growth.
6. *Dioecious* plants. Some are not strictly dioecious and have abortive ovules in the male flowers.
7. Male and female cones are organized to form an inflorescence of the panicle-type.
8. A male cone has an axis with a series of *cupules or collars* superposed one above the other.
9. Male flowers are closely packed with sterile hairs. It has a *perianth* enclosing the stalk or *antherophore*. Antherophore has two unilocular *anthers*.
10. Female cone resembles the male cones except that here a single ring of female flowers is seen above each collar. Each ring has 3-10 ovules. Each ovule represents a female flower.
11. The female or ovule has three envelopes or integuments enclosing the nucellus. The inner one elongate into a *micropylar tube* or a style-like structures. In mature ovule, the nucellus surrounds the functional embryo sac.
12. The fertilized ovule is called zygote(one zygote in *G. gnemon*) or more zygotes in *G. ula*.
13. The embryos are pushed into the cellular endosperm by the primary and secondary suspensors. Mature seed shows onlyone embryo.

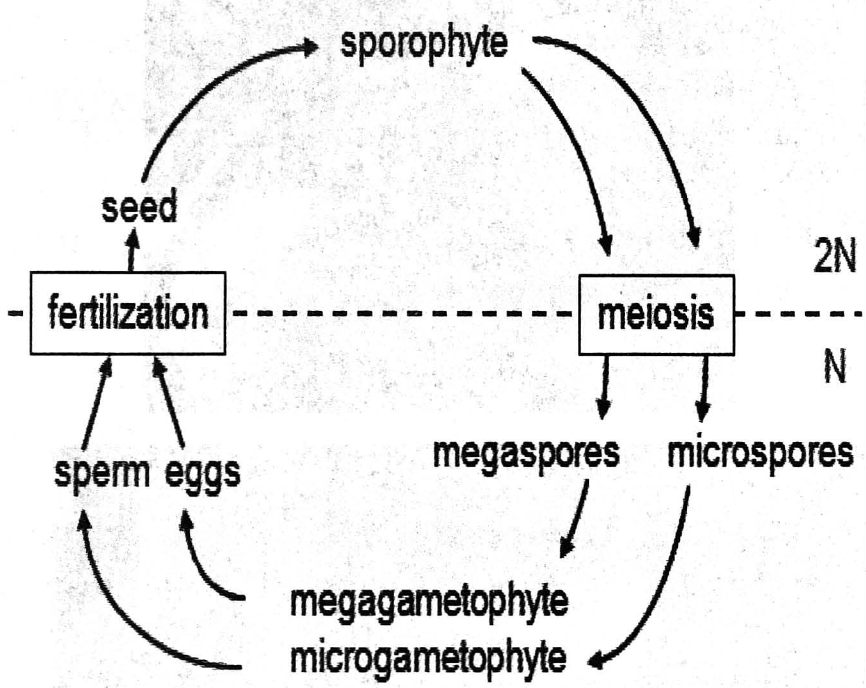
14. Male Gametophyte: The microspore has a thick, minutely spinescent *exine* and a thin *intine*. At the time of dehiscence, a pollen grain has a *prothallial cell, generative cell* and *tube nucleus*.
15. No archegonia are formed. Female gametophyte functions as an egg. Any of the nuclei towards the micropylar end may be fertilized.
16. The pollen grains are air-borne and fall into the pollen chamber. The pollen tube grows and enters through the nucellus. It reachs the embryo sac, Pollen tubes bursts, male gamete fuses with the egg and zygote formed.
17. The zygote is the first cell of the sporophyte. Polyembryony is common feature of certain species of *Gnetum*. Many embryos begin to develop. Only one survives and the remaining ones degenerate.
18. Mature seed is green to red in colour. The seed shows epigeal germination after one year.

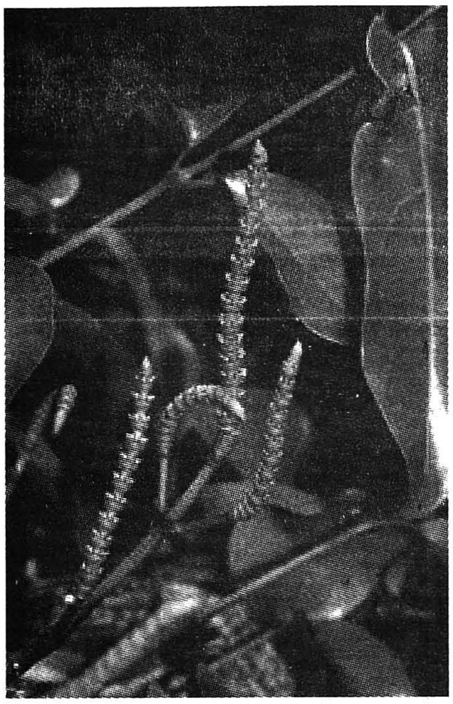
yKChid's Astro Cite

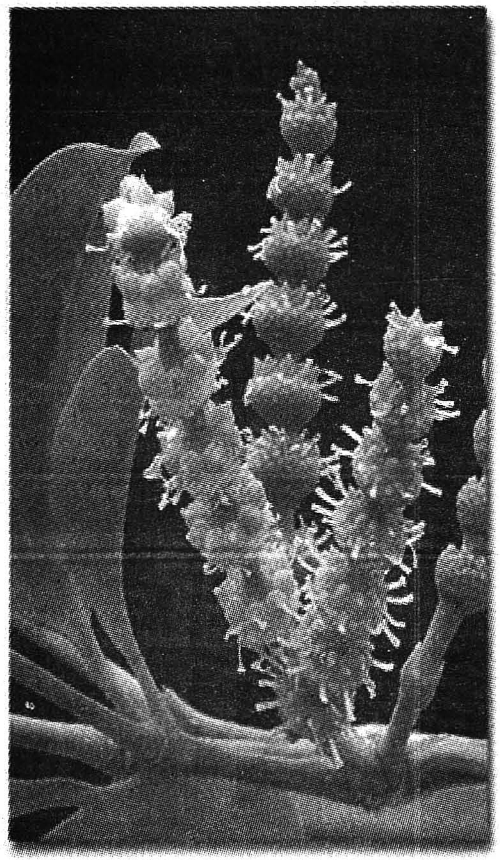












ECONOMIC IMPORTANCE OF GYMNOSPERMS

Gymnosperms account for 75 percent of the world's timber and a large amount of the wood pulp is used to make newsprint and other paper. Gymnosperm wood is strong and free of knots. It is used to manufacture music instrument like violins, house framing, plywood production, structural beams, pulpwood, railroad ties, fences, posts, boxes, and crates. Gymnosperm woods are frequently used in landscaping of parks and gardens because of their evergreen habit and symmetrical appearance

In addition to the wood and paper industry, gymnosperms are important in making resin and turpentine. Resin, the sticky substance in the resin canals of conifers, is a combination of turpentine, a solvent, and a waxy substance called rosin. Turpentine is an excellent paint and varnish solvent but is also used to make deodorants, shaving lotions, medications, and limonene-a lemon flavoring used in the food industry. Resin has many uses; it is used by baseball pitchers to improve their grip on the ball and by batters to improve their grip on the bat; violinists apply resin to their bows to increase friction with the strings; dancers apply resin to their shoes to improve their grip on the stage.

a) Construction purposes: Many conifers such as pine, cedar, etc., are sources of the soft wood used in construction and packing.

b) Medicinal uses: An anticancer drug Taxol is obtained from *Taxus*. Many species of Ephedra produce ephedrine, which can be used in the treatment of asthma and bronchitis.

c) Food source: Many gymnosperm seeds contain fatty oils.-These have, however, not been exploited commercially because they find greater use in being eaten raw as nuts.The seeds of *Pinus gerardiana* (known as chilgoza) are edible.

d) Source of resins: Resins are plant exudates which make the wood resistant to decay.-The resins are insoluble in water but soluble in organic solvents.-The superior grade resin is used in paper sizing, varnishes, enamels, plasters, medicines and ointments.-The inferior grades go in the manufacture of yellow laundry soap, printing ink, oilcloth, insulators, oil and grease, insecticides, adhesives, plastics, disinfectants and shoe polish.-Metal resonates, which are made by adding small quantities of metals such as lead and magnesium to aldehyde modified resin, are much valued as paint drier. Resins are used commercially for manufacturing sealing waxes and waterproof paints. A type of resin known as turpentine is obtained from various species of Pinus.

e) An Oleoresin (also called pine gum, pine pitch or turpentine) is the mixture of rosin and essential oil.-The residue after the distillation of oleoresin is called the gum rosin or colophony.-Rosin is also obtained by solvent extraction of old stumps.-Such rosin is called wood rosin.-USA is the largest producer of turpentine followed by France and other European countries, India and other East Asian countries

(f) COPAL: Copals belong to the group hard resins, which contain only a little essential oil.-These are much valued in the varnish industry because of their high melting point and hardness.-The copal is obtained both from living and fossil trees.

(g) AMBER : It is a fossil resin.-It occurs near eastern shore of the Baltic, Sicily, Madagascar and Myanmar (Burma). Amber is yellow brown to black, hard and brittle with an aromatic odor. It is obtained through mining. It is used in medicine and X-ray therapy. It is reported that blood does not coagulate when kept in amber containers. It is also used for beads, carving, and other ornaments, cigarette and cigar holders and mouthpieces of smoking pipes. Fossilized amber with plants, animals and insects remains is helpful in studies regarding of life on earth.

Resin

- The resins are the complex oxidation products of various essential oils
- The resins are secreted in ducts and canals of the plants
- They are derived from the plant parts in form of fluid, which gradually harden due to evaporation of the oil they contain
- They are insoluble in water, but soluble in ether and alcohol

Bark and Seeds

- The decoction of seeds of *Dioon* is used for neuralgia
- A paste of bark & seeds of *Cycas* mixed with coconut oil is used as poultice for sores and swelling.
- Oil obtained from seeds of *Pinus* seeds is used as dressing of wounds & ulcers.
- Drug obtained from *Ephedra* sp. used in treatment of asthma ,hay fever and cold.

Amber (*Pinites succinifera*)

- **Extremely hard and brittle**

Used in :

- X-ray therapy, in preparation of blood container, mouth pieces of pipes, cigarette holder

Turpentine oil

Obtained from

- *P.roxburghii*
- *P. insularis*
- *P. wallichiana*

Used in :

- Painting

Rosin (Sps. Of *Pinus*)

- **Rosin is a brittle, friable and faintly aromatic solid**
- **Used in :**
- Paper sizing,
- Varnish making
- Making of soap
- Sealing wax
- Printer ink
- Grease
- lubricants

Canada Balsam (*Abies balsamea*)

- Resin does not crystallize on drying & has a high refractive index.

Use:

- For mounting microscopic slides.

Leaves

Ginkgo

Heart,lungs,circulatorydisease

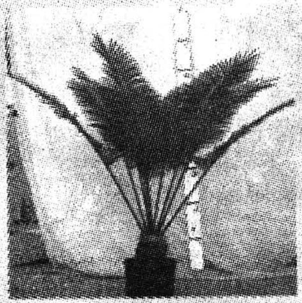
Taxus

Asthama,bronchitis,epilepsy

Cupresses

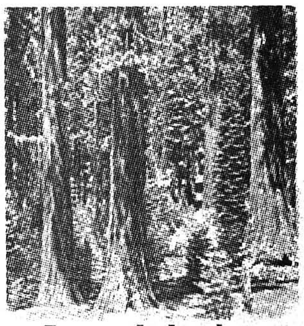
Vermifuge properties

Cycas



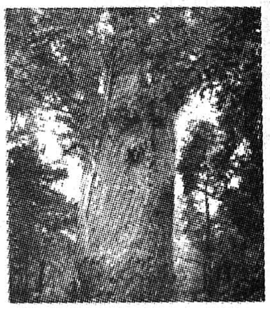
Stomach & skin disorder,vomitting

Other timber yielding plants



Sequoia (red wood)

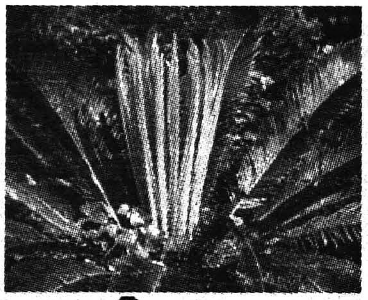
Taxodium distichum



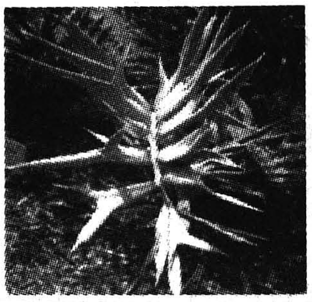
Agathis australis

Podocarpus

Sago : Obtained from



Cycas sp.

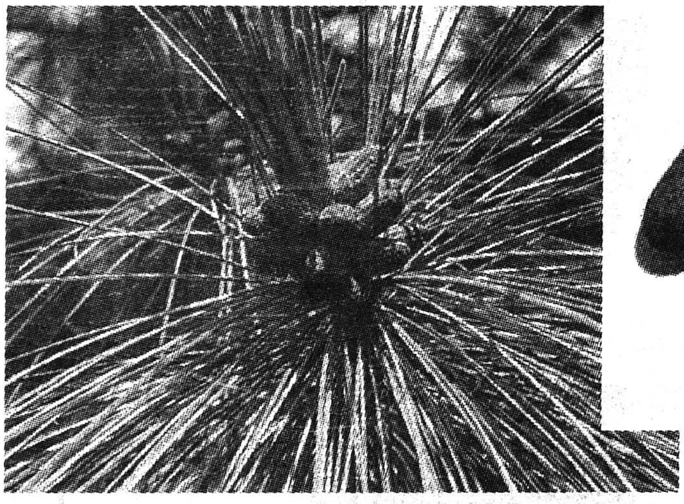


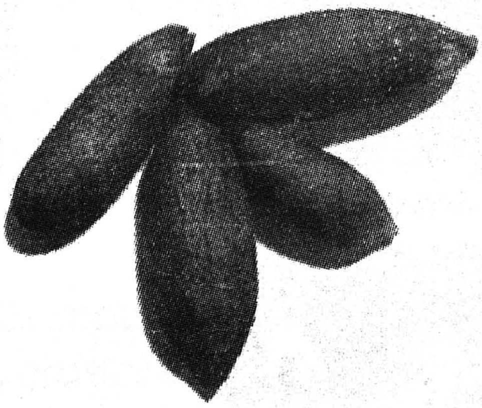
Encephalarios sp.

Zamia sp.

Macrozamia sp.

Chilgoza tree & seeds





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15. Write notes on alterantion of genrations in Bryophytes with illustration.

16.Write notes on ecological significance of Bryophytes.

17.Describe salient features of Lycopsida

18.Give general account of fossil Pteridophytes.

19. Write a genral account of Cycadales.

20. Write a brief account on evolutionary tendencies in Gymnosperms

Part C (3 x 15 = 45 Marks)

21. Give the outline of Fritsch's system of classification of algae

22. Compare sporophytes of *Riccia, Marchantia* and *Anthoceros*. Which one is the advanced?

23.Describe the characteristic features and brief account of the classification of Bryophytes..

24.Give an account of Stelar evolution in Pteridophytes.

25.Give a detailed account of classification of Gymnosperms based on K.R. Sporne.